TISA Working Group Update

CERES TISA Sublead: D. Doelling

TISA: B. Branch, A. Gopalan, E. Kizer, P. Mlynczak, C. Nguyen, M. Nordeen, M. Sun, J. Wilkins, F. Wrenn

GEO and Imager calibration: R. Bhatt, C. Haney, B. Scarino

Kathleen Dejwakh & subsetter team

CERES Science Team Meeting

Virtual Covid-19 Meeting, May 11-13, 2021

Outline

- Terra mean local time drift study
- CERES TISA Edition 5 framework coding progress
- GEO and MODIS/VIIRS imager calibration
- GEO Ed5 shortwave narrowband to broadband progress

TISA and GEO/imager Calibration Publications

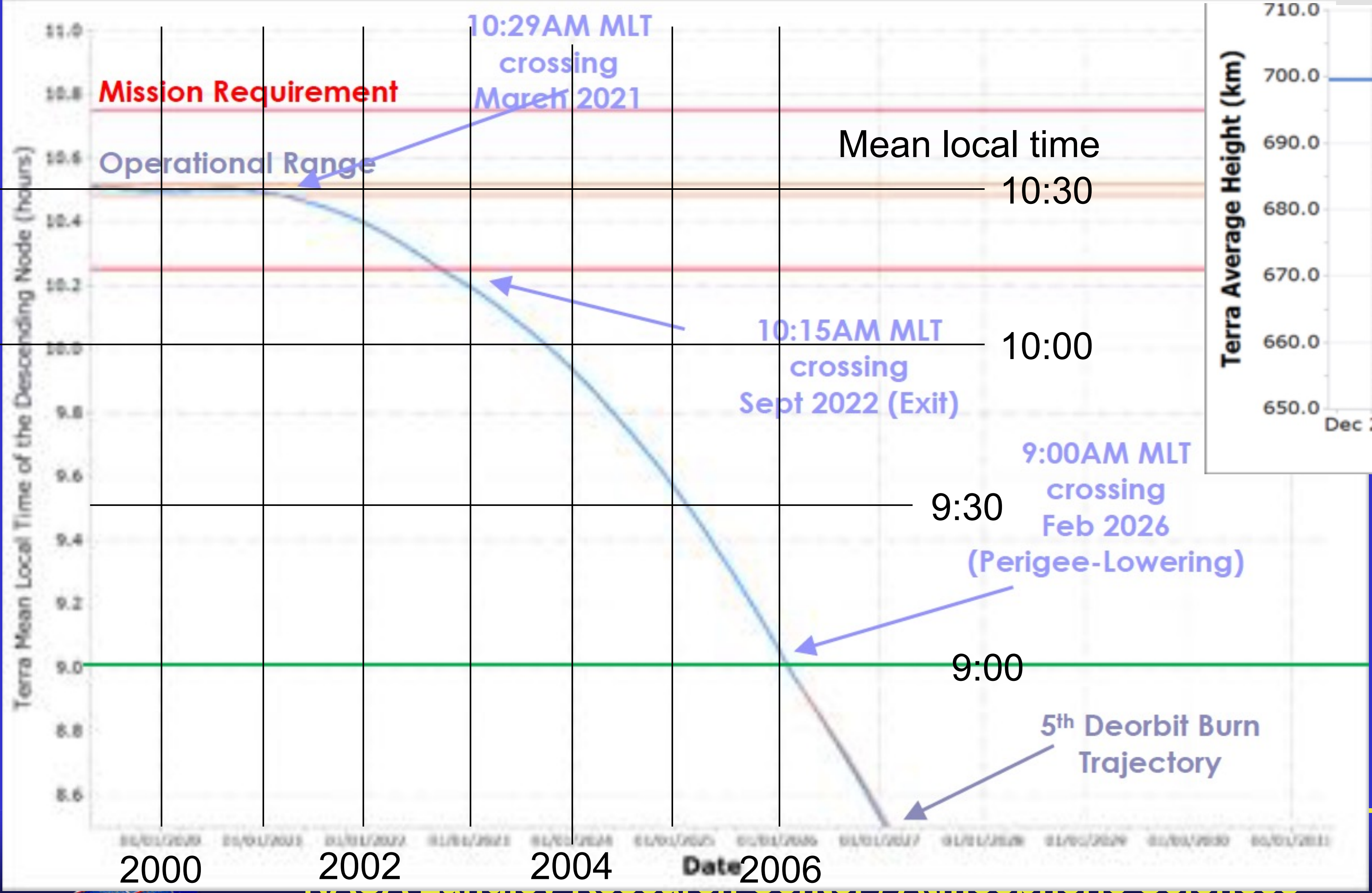
- **TISA**
- Moguo Sun, David R. Doelling, Norman Loeb, Joshua Wilkins, Ryan Scott, Le Trang Nguyen, Pamela Mlynczak, Clouds and the Earth's Radiant Energy System (CERES) FluxByCldTyp Edition 4 Data Product, submitted to Journal of Atmospheric and Oceanic Technology, submitted March 8, 2021

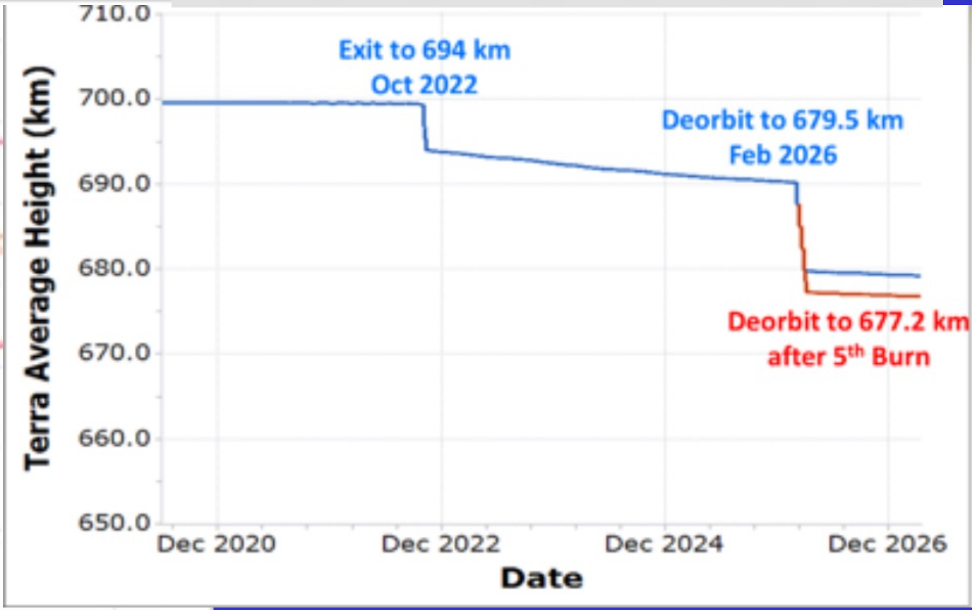
- **CALIBRATION**
- Scarino B, Doelling DR, Bhatt R, Gopalan A, Haney C. Evaluating the Magnitude of VIIRS Out-of-Band Response for Varying Earth Spectra. Remote Sensing. 2020; 12(19):3267. https://doi.org/10.3390/rs12193267 (NPP and N20 VIIRS do not use the same solar spectra)
- Bhatt, R.; Doelling, D.R.; Coddington, O.; Scarino, B.; Gopalan, A.; Haney, C. Quantifying the Impact of Solar Spectra on the Inter-Calibration of Satellite Instruments. Remote Sens. 2021, 13, 1438. https://doi.org/10.3390/rs13081438
- David Doelling, Changyong Cao, and Xiaoxiong (Jack) Xiong, GSICS recommends NOAA-20 VIIRS as reflective solar band (RSB) calibration reference, GSICS Quarterly, Vol. 14 No 4, 2021, doi: 10.25923/jmbt-d994 (NOAA and NASA N20-VIIRS visible calibration within 0.2%)

Regional flux Impact of drifting Terra orbit

Terra Orbital Drift

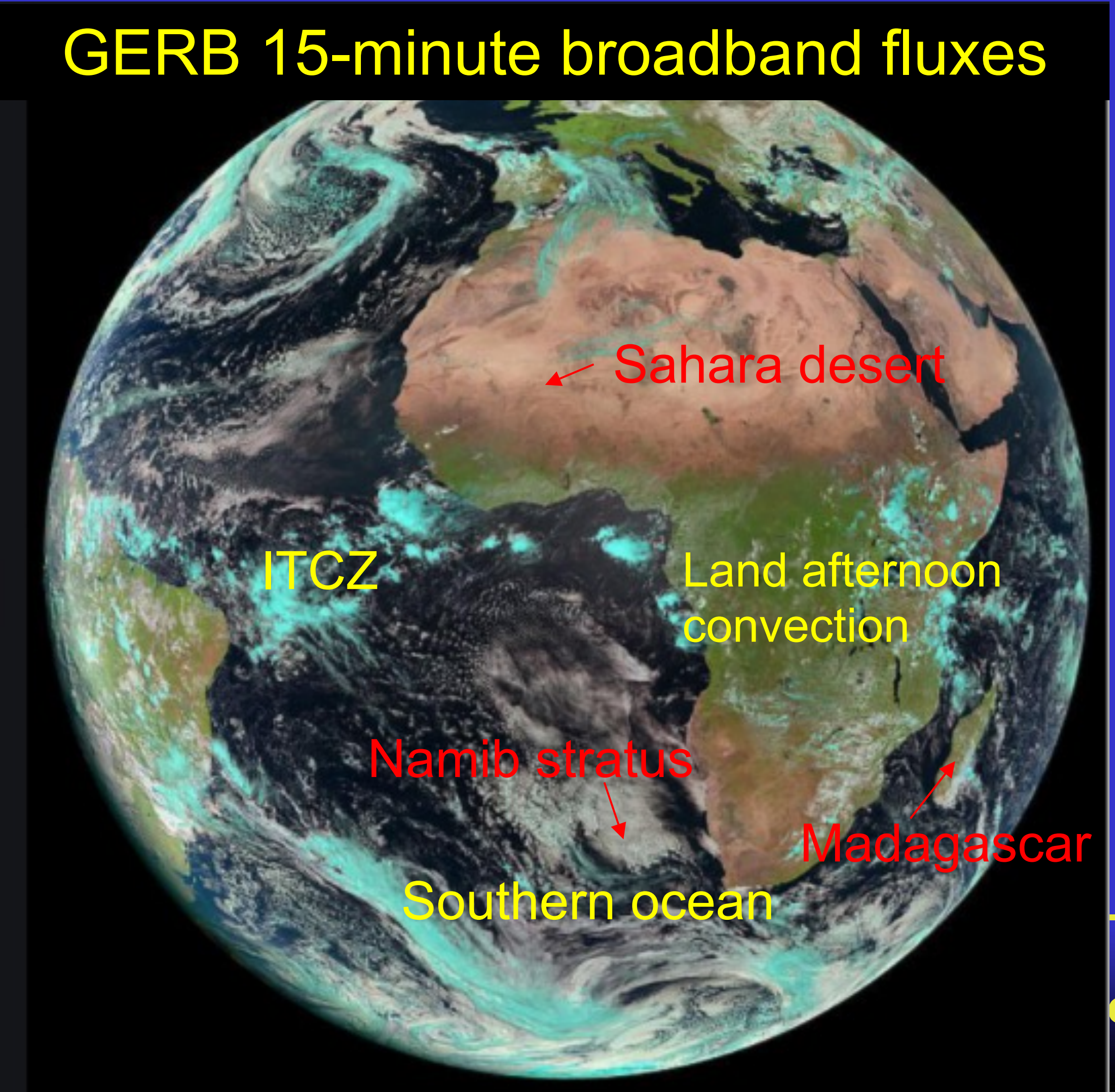
MODIS/VIIRS Science Team Meeting
November 19, 2020





- Terra to drift out of controlled 10:30 MLT orbit during Fall 2022

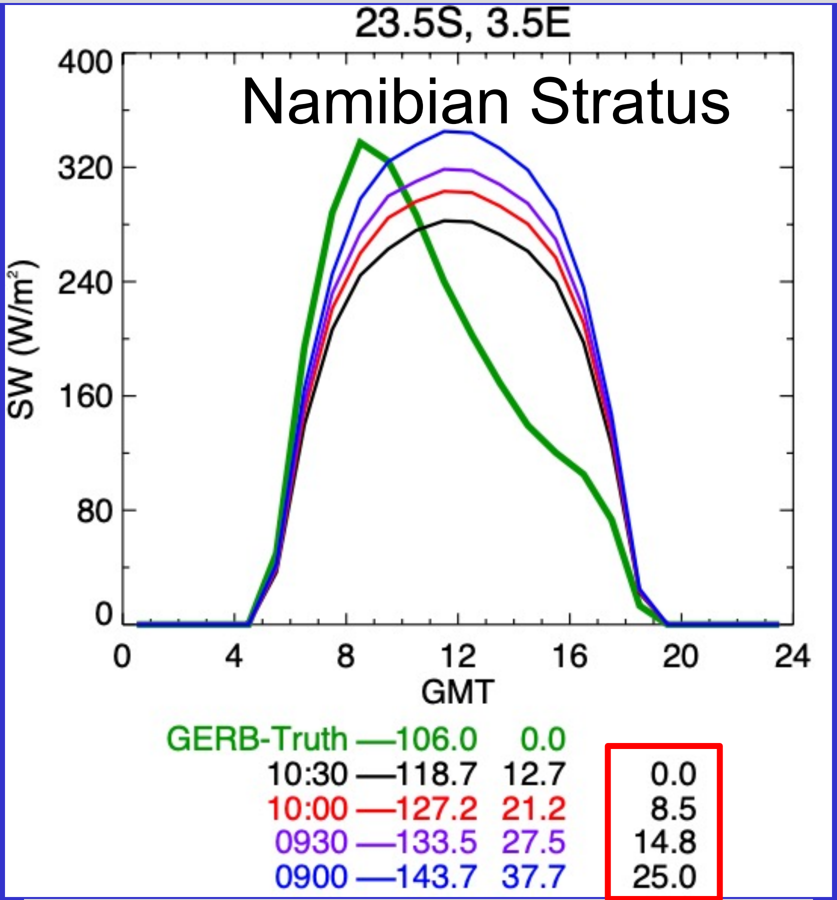
Impact of the Terra MLT drift on CERES SSF1deg products



- Use 15-minute instantaneous GERB fluxes
  - Compute GERB-10:30 monthly fluxes using Terra 10:30 sampling (no Terra fluxes are used)
  - Compute GERB-10:15 monthly fluxes using Terra 10:30 minus 15minute sampling
- Compare the GERB-10:15 with the GERB-10:30 monthly fluxes
- SSF1deg-Terra product temporal interpolation
  - SW temporal interpolation accounts for change of SZA over the day. If the scene did not change, there would be no change in the daily SW mean flux. Only regional diurnal scene changes would observe change in SW flux
  - LW employs linear interpolation between Terra measurement and a half sine fit to take account land heating

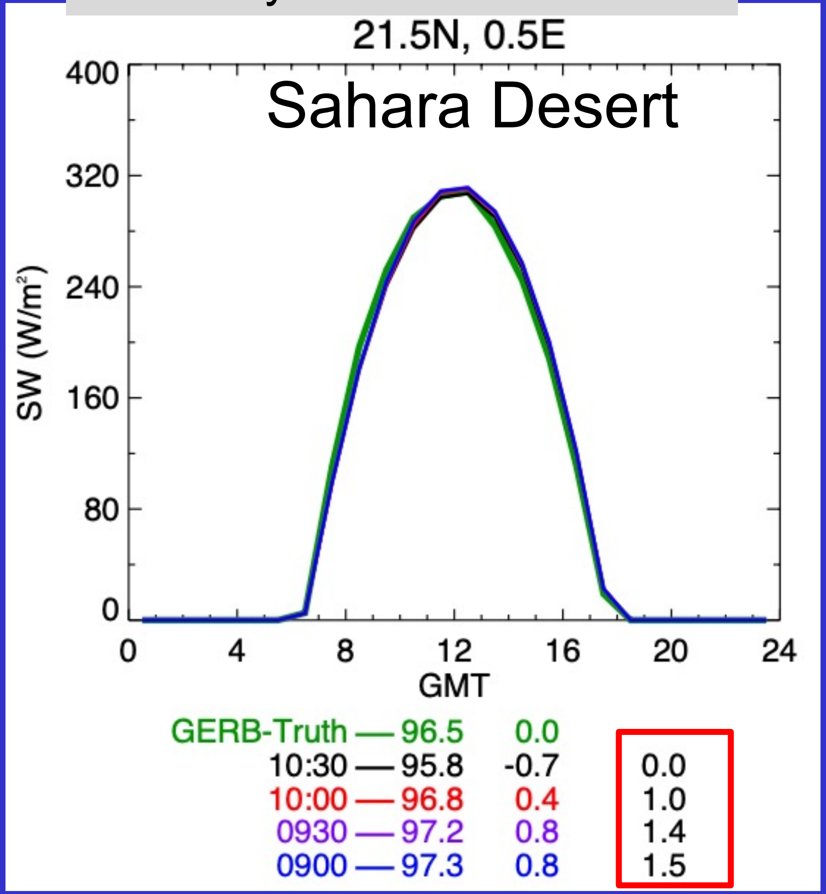
Monthly Hourly SW

Maritime stratus peaks during morning



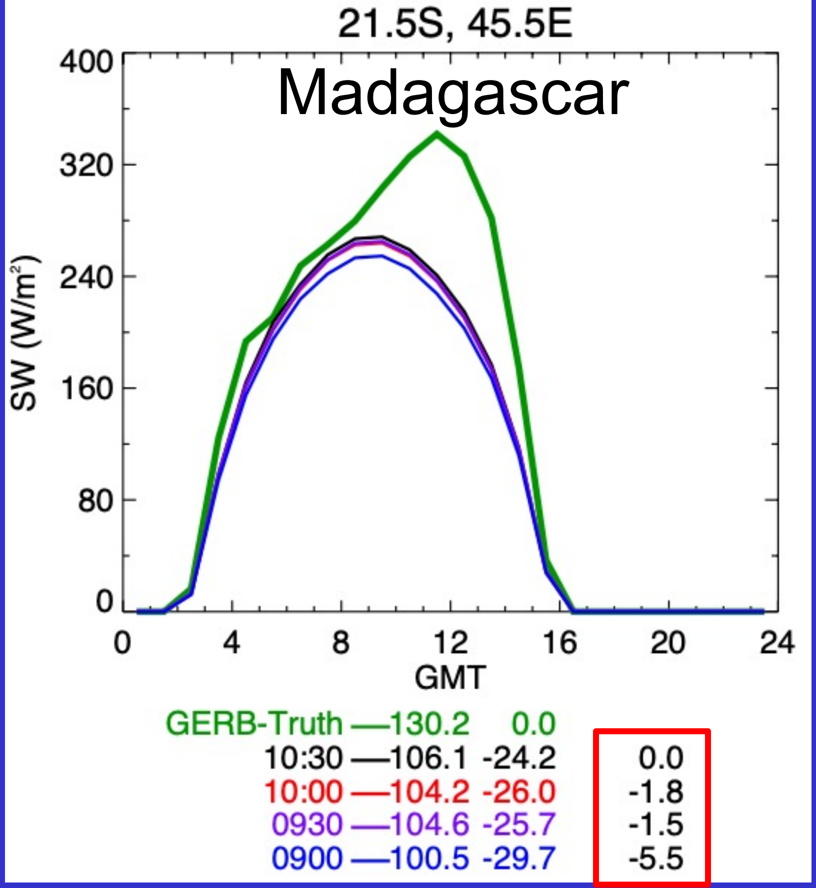
Terra orbit drift will increase the SW flux

Desert symmetric about noon



Terra orbit drift will not impact desert SW fluxes

Land afternoon convection

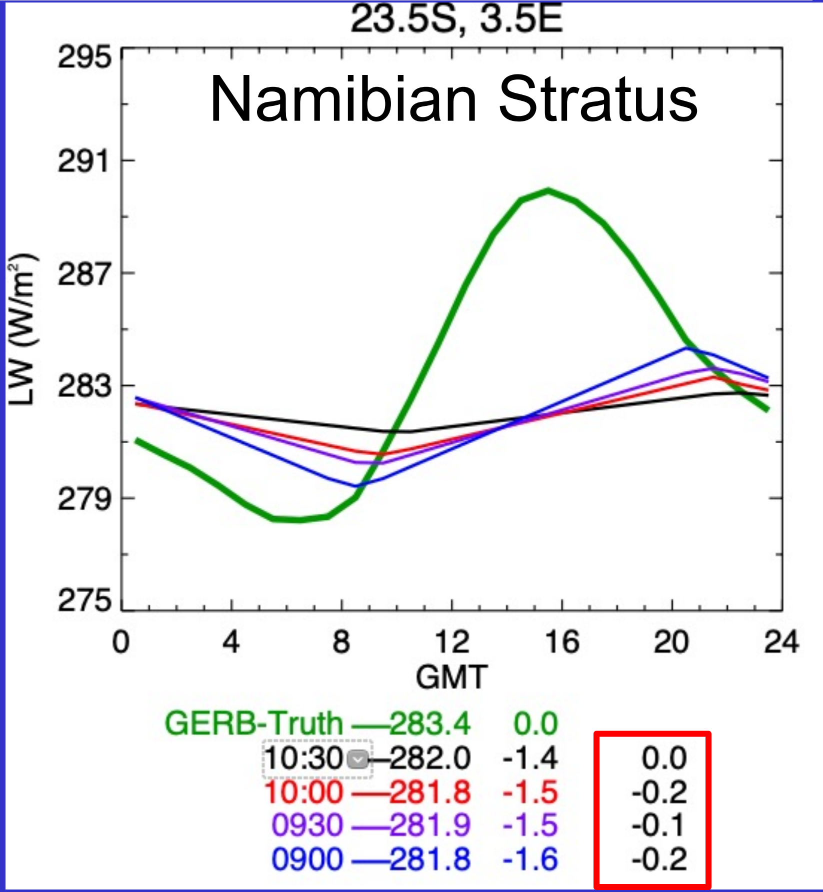


Terra orbit drift will slightly decrease SW fluxes

- SW albedo diurnal models are symmetric about noon

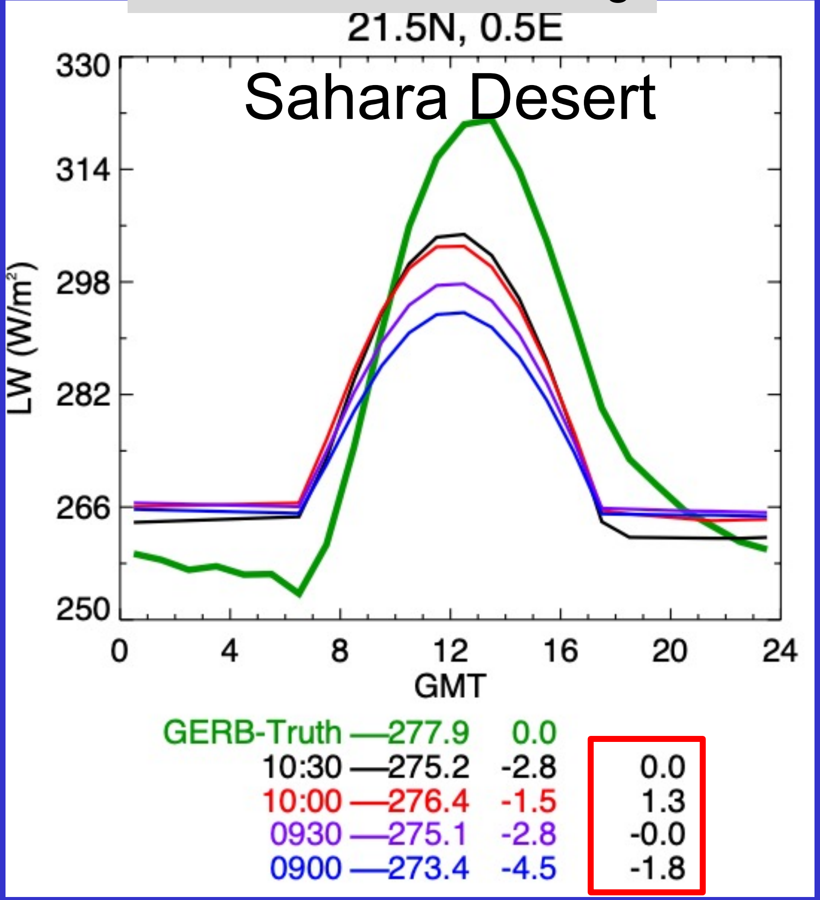
Monthly Hourly LW

Maritime stratus peaks during morning



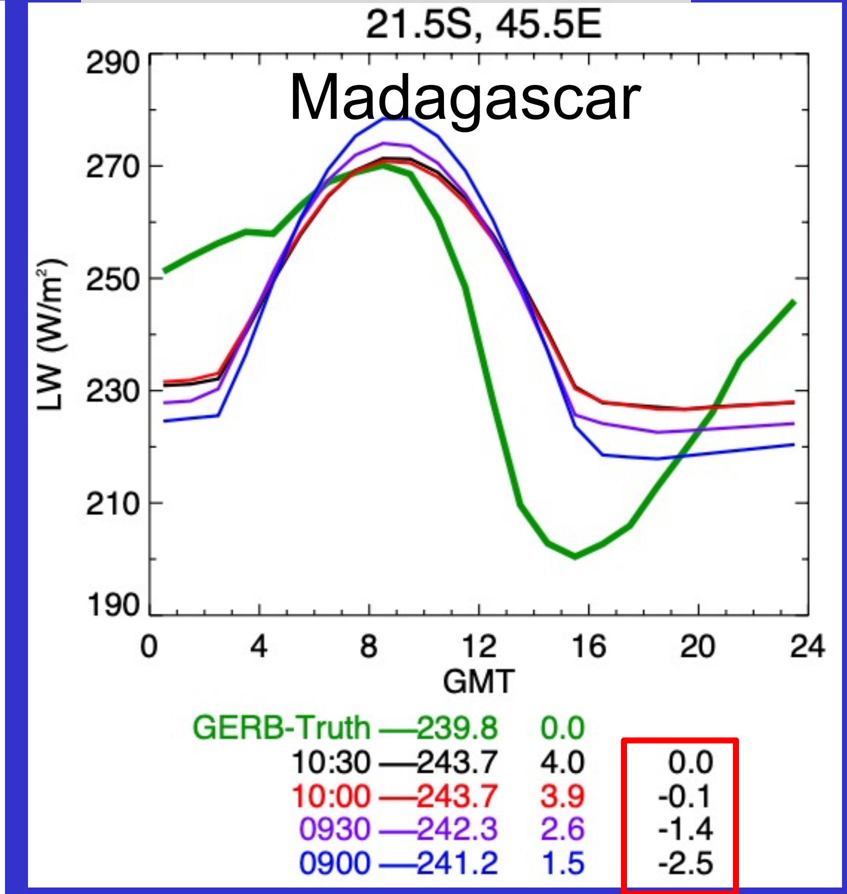
Linear interpolate LW flux obs to compute monthly mean

cloud free land heating



Employ half sine fit to estimate LW flux due to land heating

Land afternoon convection

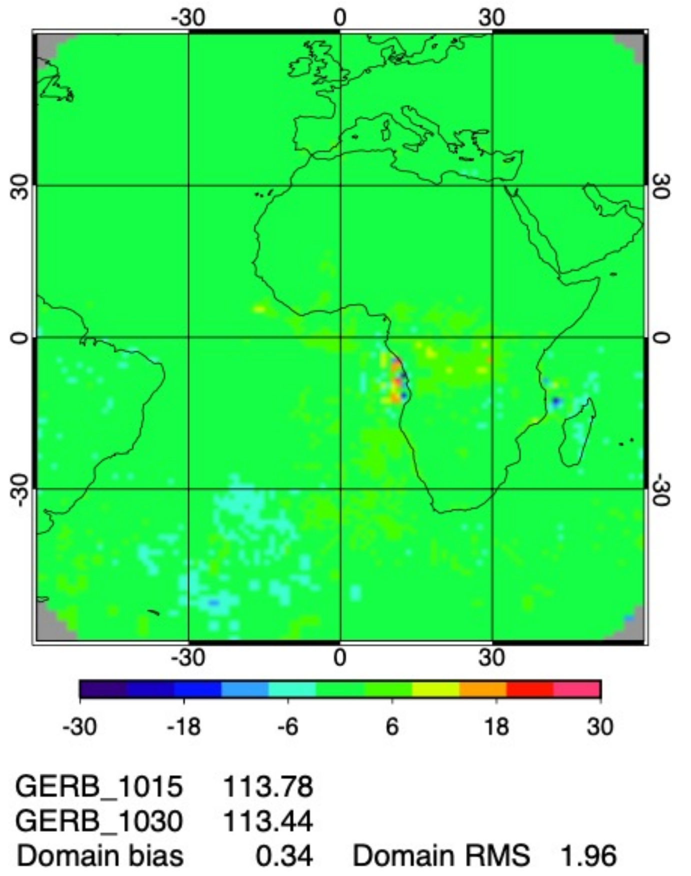


land convection starts before noon and peaks at sunset

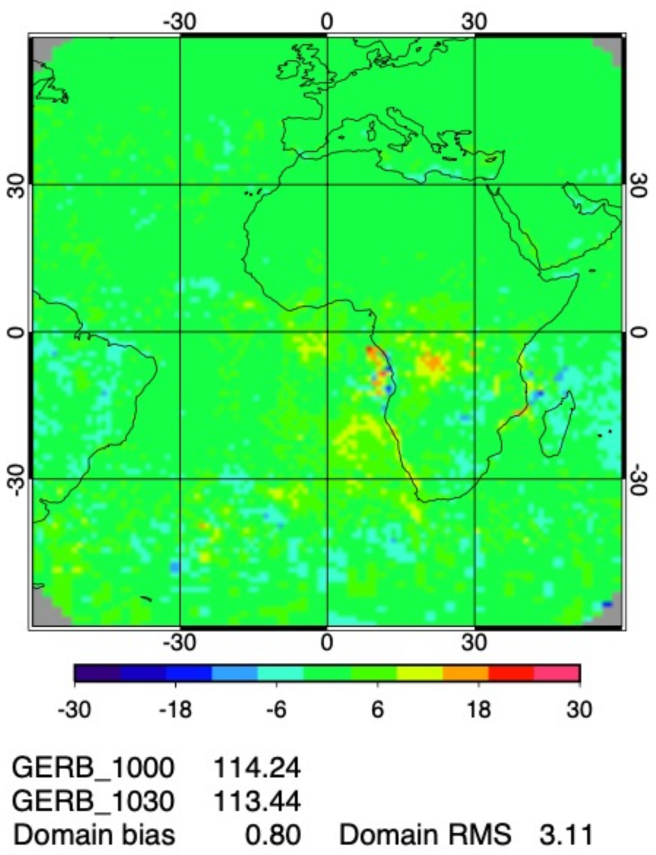
- The monthly LW fluxes less dependent on measurement time, but do not reflect the true diurnal LW shape
- The well-timed Terra observations can fortuitously reasonably estimate the monthly flux

Monthly Mean SW

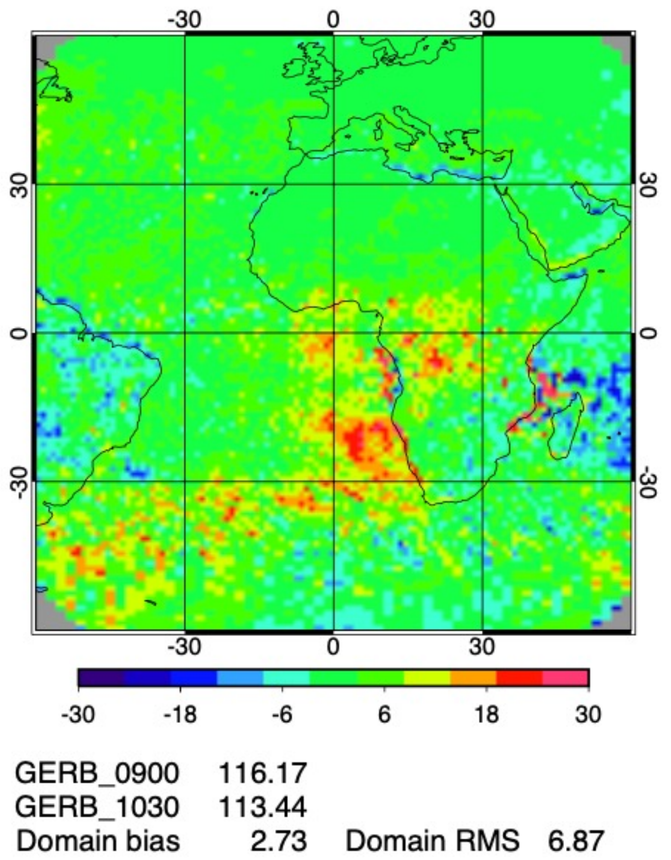
10:15-10:30



10:00-10:30



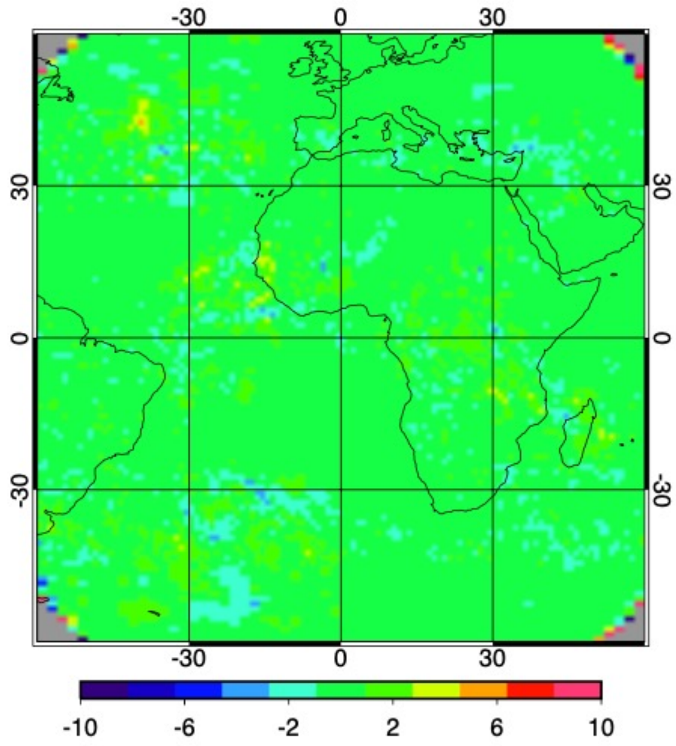
9:00-10:30



- Terra orbit drift seems to increase the monthly mean SW flux.
- Maritime stratus has greater impact than land afternoon convection

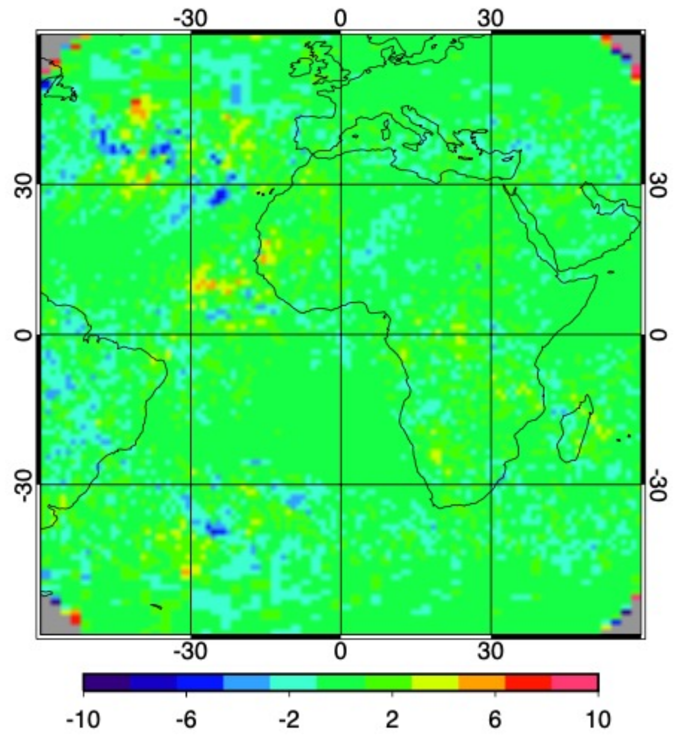
Monthly Mean LW

10:15-10:30



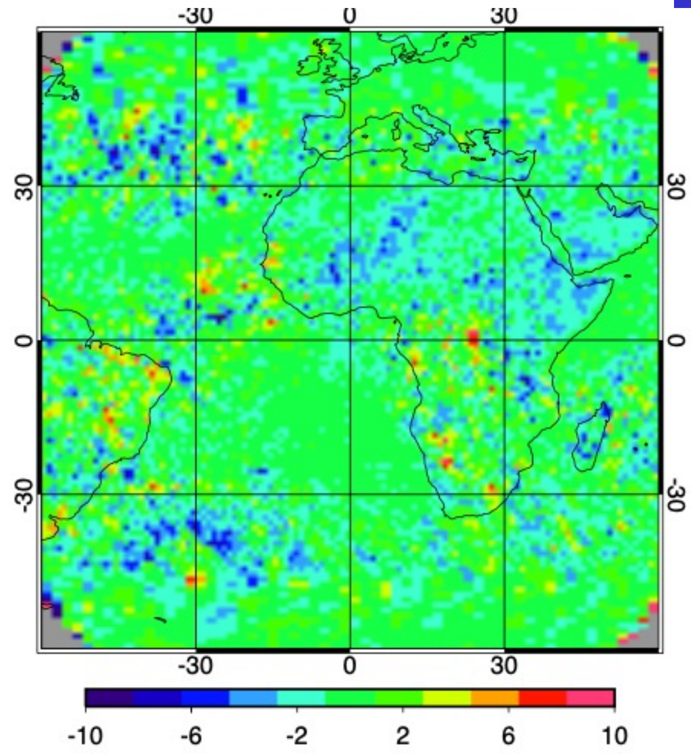
GERB_1015 243.42
GERB_1030 243.38
Domain bias 0.04 Domain RMS 0.89

10:00-10:30



GERB_1000 243.35
GERB_1030 243.38
Domain bias -0.03 Domain RMS 1.20

9:00-10:30



GERB_0900 243.01
GERB_1030 243.38
Domain bias -0.37 Domain RMS 1.98

- Terra orbit drift seems to decrease the monthly mean LW flux, but is very noisy

Summary of Terra MLT drift

Wm-2	SW Monthly bias, rms	SW Daily RMS	LW Monthly Bias, rms	LW daily RMS
10:15-10:30	0.3, 2.0	5.6	0.0, 0.9	3.0
10:00-10:30	0.8, 3.1	9.3	-0.0, 1.2	4.7
9:45-10:30	1.3, 4.3	12.3	-0.1, 1.6	6.1
9:30-10:30	2.0, 5.6	14.8	-0.2, 1.7	7.0
9:15-10:30	2.7, 6.9	17.7	-0.4, 2.0	7.8
9:00-10:30	2.9, 8.6	20.4	-0.5, 2.3	8.7

GERB domain mean SW and LW is flux 113.4 and 243.4 Wm-2

- Perform Terra MLT analysis using July 2010
- Repeat analysis for Aqua MLT drift

ED5 Framework

Special thanks to Kathleen Dejwakh and Nelson Hillyer

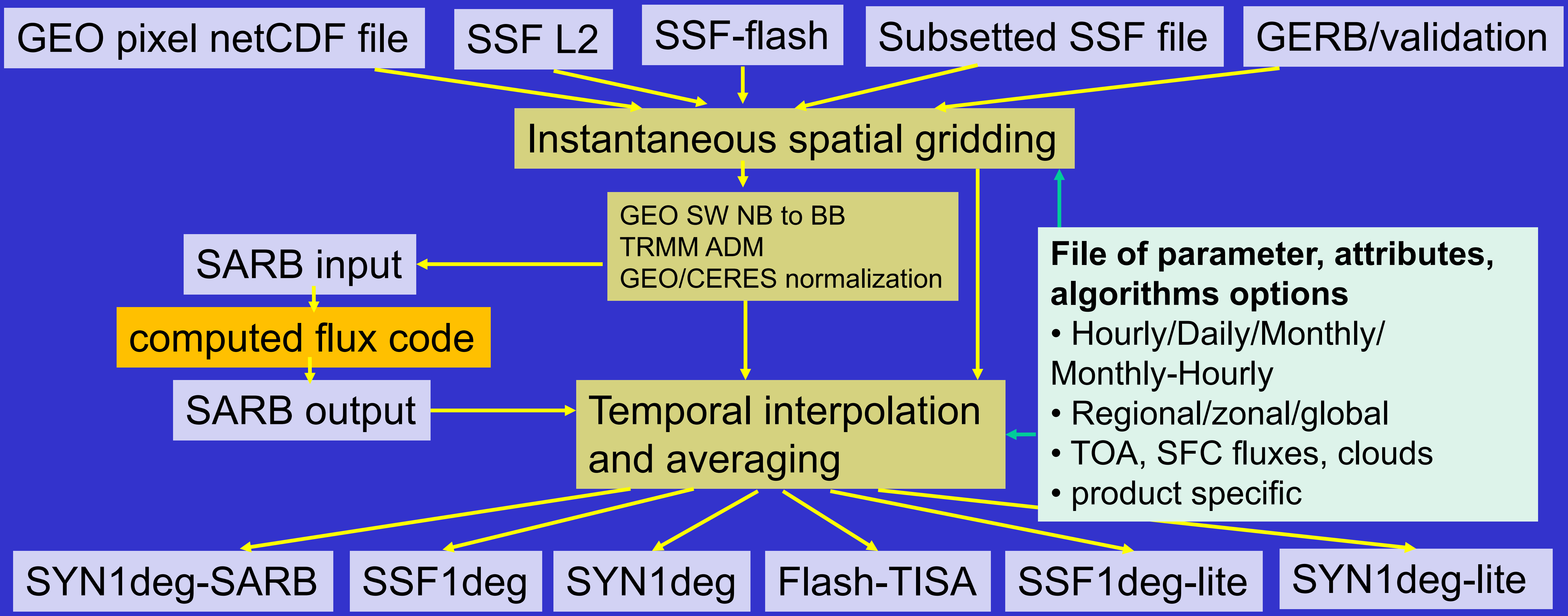
The TISA Edition 4 framework was unsustainable

- Separate (duplicated) codes for each (SSF1deg, SYN1deg, CldTypHist) product that contained the same spatial averaging, temporal interpolation and temporal averaging
- The number of parameters, cloud-layers, grid and temporal resolution was hard coded throughout the code
- The placement of the GEO narrowband to broadband code made it impossible to test new channel radiances or parameters
- SARB code is contingent on TISA (could not be developed in parallel)
- Trying to develop new science or algorithms is difficult in this framework. Only one person knows the innerworkings of the code. All test code was intertwined in the framework. Only delivered code was version controlled.

TISA Edition 5 framework

- Prior to 2020, the framework scope, existing code flow and status, object-oriented coding principles, and version control was hashed out.
- Framework coding started in earnest last year.
- The Edition5 goals
  - Combine in a single code the SSF1deg and SYN1deg official product codes and their lite counterparts required to process EBAF in near real-time.
  - The introduction of the SYN1deg-SARB product, to remove the contingency of SYN1deg to be processed before the computation of SYN1deg surface fluxes
  - Allow FLASHFlux to use the same TISA code for their temporally averaged products
  - Move the GEO narrowband to broadband code into GEO spatial gridding
  - Allow for selection of spatial gridding and temporal resolution
  - SW diurnal models are determined while spatially gridding SW (footprint) fluxes

Ed5 framework flowchart



Ed5 framework scalability, configurable, flexible

Spatial and temporal resolution

- Spatial gridding: various equal angle or equal area gridding approaches
- Temporal gridding: GMT or local binning, various temporal bins, 0.5, 1.0 hourly, etc.
- Set during compilation

Cloud-type

- Number of cloud-types or layers dependent on product processed
- Ed5 SSF/SYN1deg 3 layers
  Ed4 SSF/SYN1deg 4 layers
- CldTypHist or Ed5 SARB input 3x3 cloud-types
- FluxByCldTyp 7x6 cloud-types
- SSF/SYNdeg-lite total cloud-only

Input Sources

- Instantaneous footprint or pixel level files
- Ed4/Ed5 SSF L2
- Ed4/Ed5 SSF gridded subsetted for lite codes
- GEO pixel level netCDF files
- SSF L2 FLASHFlux
- SARB netCDF
- GERB and other validation datasets

Output files

- By default, will contain the parameters, cloud-types, and parameters organization similar to the input file
- Customized by specific products
- HDF, netCDF, etc.

Ed5 framework scalability, configurable, flexible

Library

- Temporal interpolation library: SW directional model, LW half-sine fit, linear interpolation
 Temporal averaging: cloud weighted, log (optical depth) weighted, total cloud from layers
- GMT or local time-based temporal resolution and time integrated SZA algorithms, equal angle or area spatial gridding
- Zonal, global flux weighting strategies
- Parameters have assigned attributes that determine valid range, temporal interpolation, spatial and temporal averaging strategies
- Science, validation, or diagnostic (based on debugging efforts) algorithms can live in the library and do not clutter the flow of the code
- Multiple coders can simultaneously develop within framework
- Version control and code review are in place

Parameter

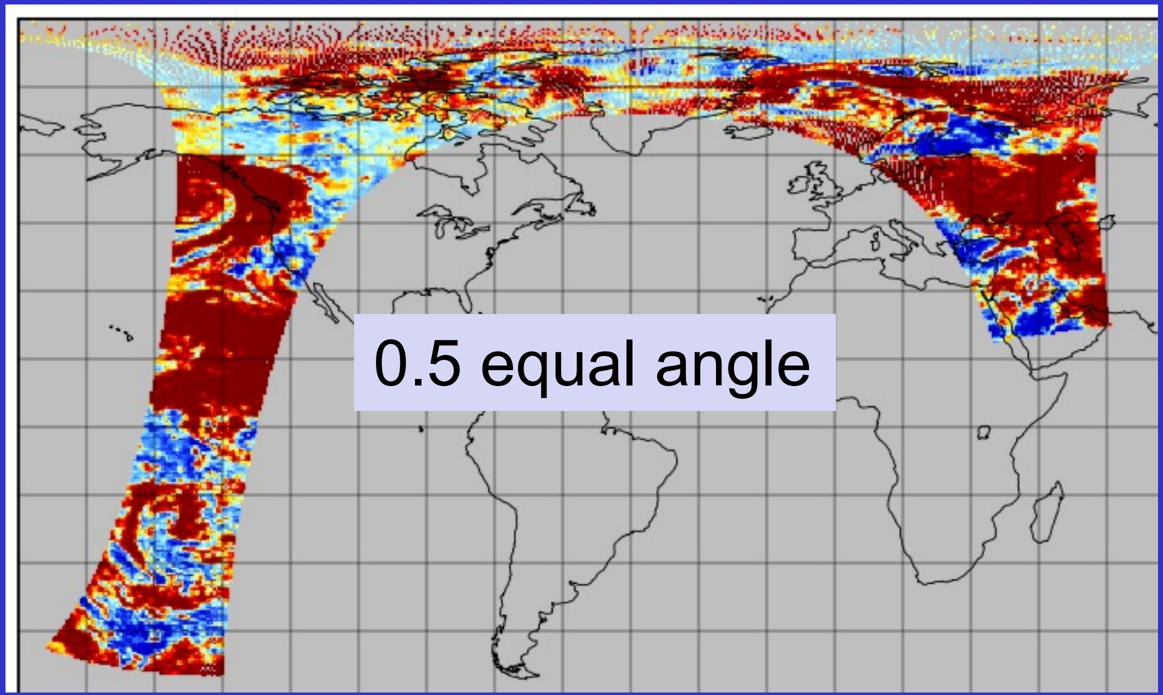
- Parameters selected by input netCDF file parameter list or specified in JSON file
- Parameters have assigned attributes that determine valid range, temporal interpolation, averaging strategies, etc.
- Parameter attributes will be listed in netCDF output file for traceability

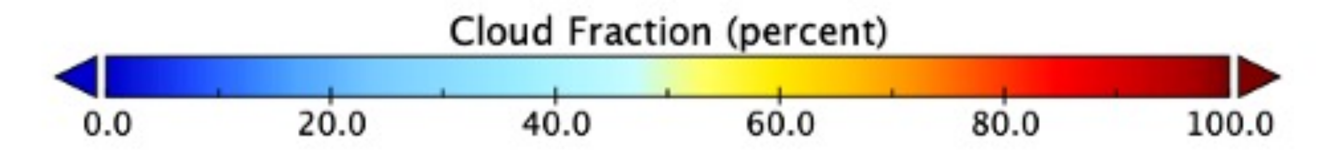
TISA Edition 5 framework milestone

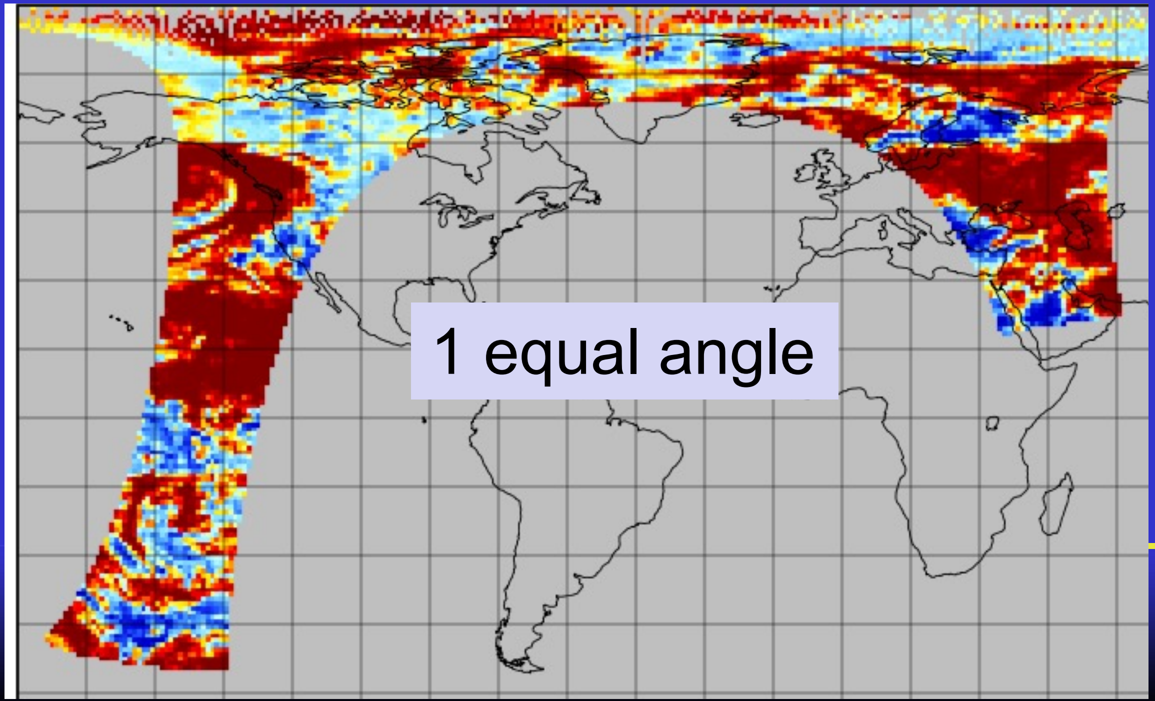
- Successful Ed5 framework end to end demonstration of cloud parameters that were consistent with their Ed4 product spatially gridded and daily/monthly regional means
- Able to demonstrate the selection of spatial gridding resolution, cloud parameters and cloud layers based on JSON input files and compile options.

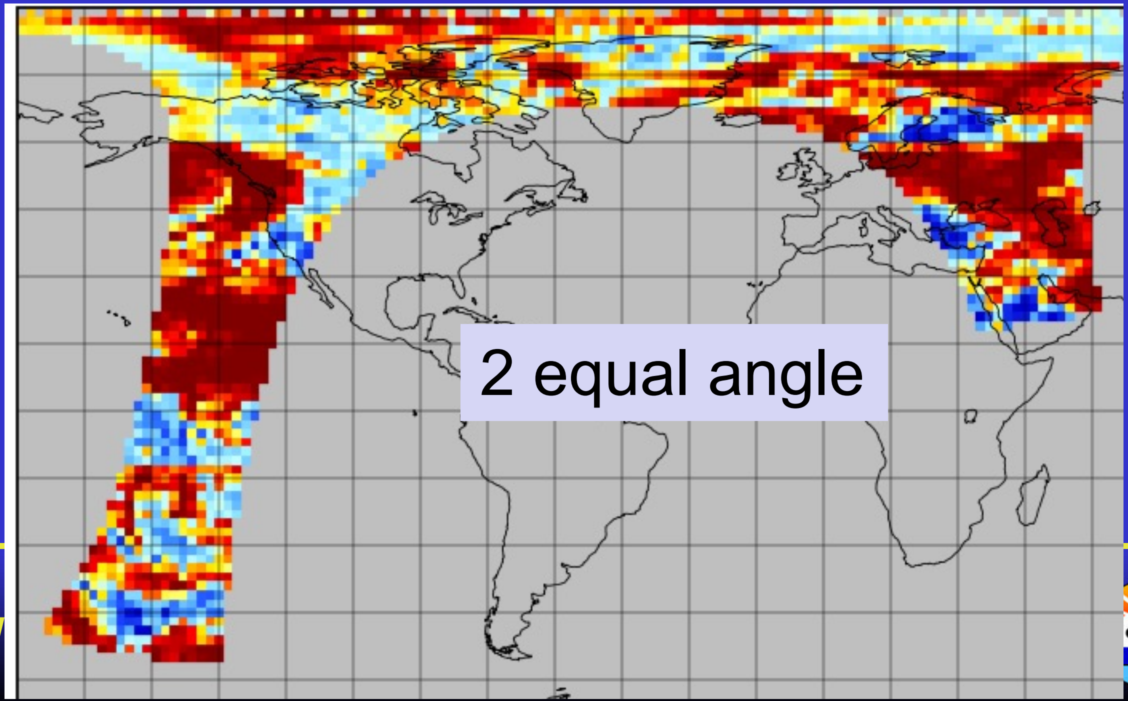
- **Next steps**
- Build GEO spatial gridding container
- Build flux container, add flux parameters, NB to BB routines, TRMM ADM
- Migrate to Ed5 framework early next year

Spatial grid resolution









Ed5 parameter attributes file

```
&CLOUD_REG_PROPERTY_INFO
 IPROP = 4,
 VarName = 'cld_od_reg',
 PropLName = 'Interpolated Cloud Visible Optical Depth',
 ValMin = -3.0,
 ValMax = 5.0,
 ValDef = 3.4028235E+38,
 Units = 'N/A',
 SpatInterpolScheme = 'None',
 TempInterpolScheme = 'Logarithmic',
 AveScheme = 'None',
 WeightScheme = 'None',
 WeightProperty = 'cld_amount_reg',
 PropertyClass = 'LevelOne'
```

```
&CLOUD_REG_PROPERTY_INFO
 IPROP = 1,
 VarName = 'cld_amount_reg',
 PropLName = 'Interpolated Cloud Amount',
 ValMin = 0.0,
 ValMax = 100.0,
 ValDef = 3.4028235E+38,
 Units = 'Percent',
 SpatInterpolScheme = 'None',
 TempInterpolScheme = 'Linear',
 AveScheme = 'None',
 WeightScheme = 'None',
 WeightProperty = 'None',
 PropertyClass = 'Base'
 /
```

```
&CLOUD_REG_PROPERTY_INFO
 IPROP = 18,
 VarName = 'cld_lwp_37_reg',
 PropLName = 'Interpolated Cloud Liquid Water Path 3.7-micron',
 ValMin = 0.0,
 ValMax = 10000.0,
 ValDef = 3.4028235E+38,
 Units = 'g_per_m^2',
 SpatInterpolScheme = 'None',
 TempInterpolScheme = 'LWP_Eqn',
 AveScheme = 'None',
 WeightScheme = 'None',
 WeightProperty = 'cld_liquid_reg',
 PropertyClass = 'LevelOne'
 /
```

Parameter attributes file	**Temporal Interpolation strategy**	**Weighting parameter for temporal averaging**
Cloud amount	Linear	None
Cloud optical depth	Log	Cloud amount
Cloud LWP	From COD, particle size	Liquid cloud amount

Ed5 framework coding example

ED5 Code calls (pass Object to Methods)

Call **CLOUD_PROPERTIES**%**dim_and_allocate**(nvars, nlons, nlats, nlayers, var_name)
Call **CLOUD_PROPERTIES**%**fill_CERES_default**()
Call **CLOUD_PROPERTIES**%**temporally_interp_cloudprop**(Cloud_Prop_ID, Dim_to_Interpolate_Along)

Corresponding Ed4 calls

- Adding a new Cloud Parameter is very hard because of the code framework.

```
ALLOCATE(incldfrac(nlon,nlat,-23:hrs_in_mnth+24,nlay))
ALLOCATE(inliqfrac(nlon,nlat,-23:hrs_in_mnth+24,nlay))
ALLOCATE(inicefrac(nlon,nlat,-23:hrs_in_mnth+24,nlay))
ALLOCATE(inlogopt(nlon,nlat,-23:hrs_in_mnth+24,nlay))
ALLOCATE(inlinopt(nlon,nlat,-23:hrs_in_mnth+24,nlay))
ALLOCATE(iniremis(nlon,nlat,-23:hrs_in_mnth+24,nlay))
ALLOCATE(inlwp_37(nlon,nlat,-23:hrs_in_mnth+24,nlay))
ALLOCATE(iniwp_37(nlon,nlat,-23:hrs_in_mnth+24,nlay))
```

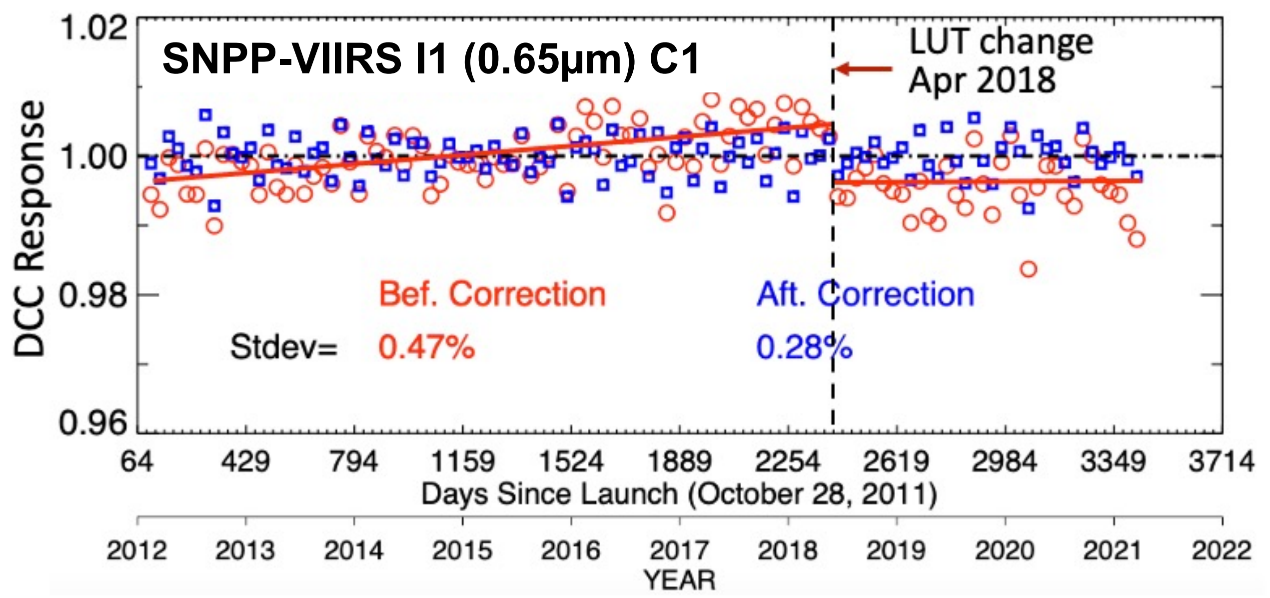
```
cld_params%liq_frac(i) = real4_dflt
cld_params%ice_frac(i) = real4_dflt
cld_params%vis_opdep_log(i) = real4_dflt
cld_params%vis_opdep_linear(i) = real4_dflt
cld_params%ired_emis(i) = real4_dflt
cld_params%liq_H2O_37(i) = real4_dflt
cld_params%ice_H2O_37(i) = real4_dflt
```

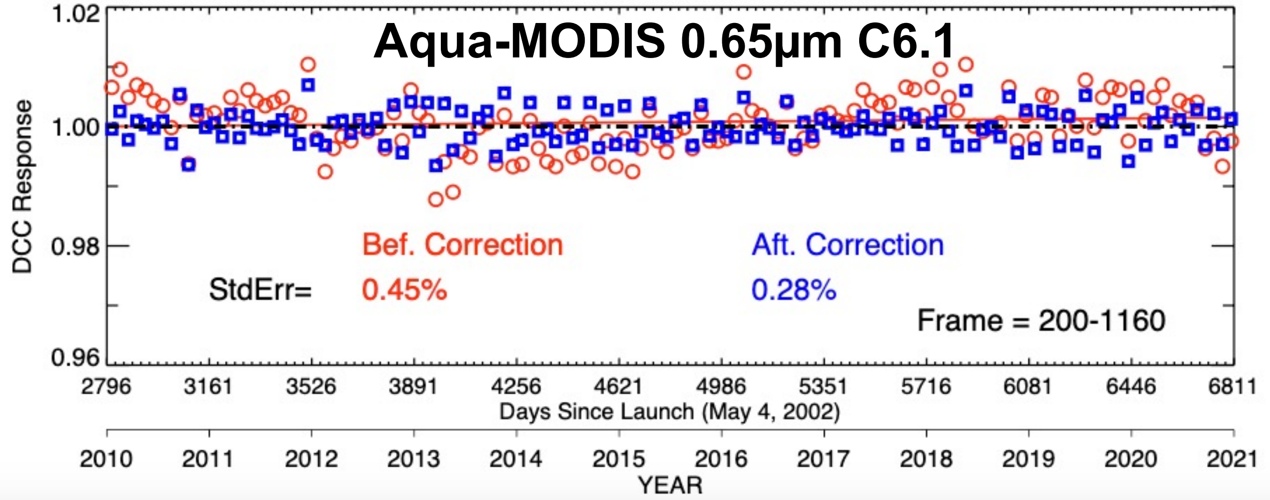
```
cldamtl      = cld_params%liq_frac
CALL get_hrboxes(cldamtl, num_meas, hrbox_nums)
CALL linear_interp_cloud(num_meas,hrbox_nums, cld_params%liq_frac)

cldamti      = cld_params%ice_frac
CALL get_hrboxes(cldamti, num_meas, hrbox_nums)
CALL linear_interp_cloud(num_meas,hrbox_nums, cld_params%ice_frac)

CALL cld_interp1(cld_area_frac, cld_params%vis_opdep_linear)
```

CALIBRATION

LEO Imager calibration drift correction

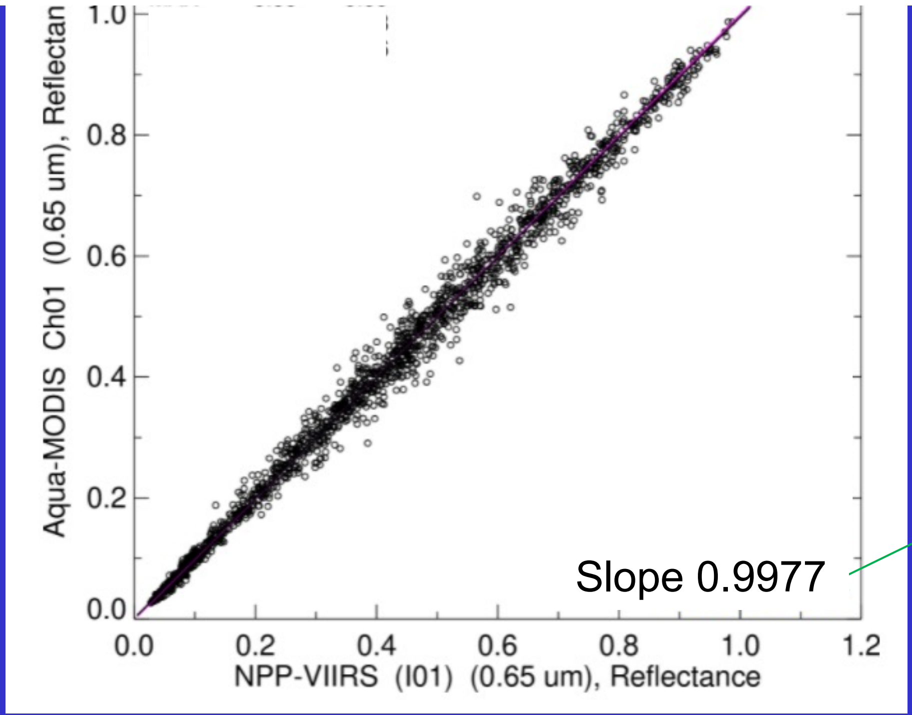
- MODIS and VIIRS L1B radiances exhibit short-term calibration drifts and discontinuities (LUT update, safe-mode incident, RVS change, etc)
- Record can be stabilized using Deep Convective Cloud invariant target (DCC-IT)-based monthly drift correction factors
  - Using 3-month DCC-IT running mean
  - Possible to implement in near real time



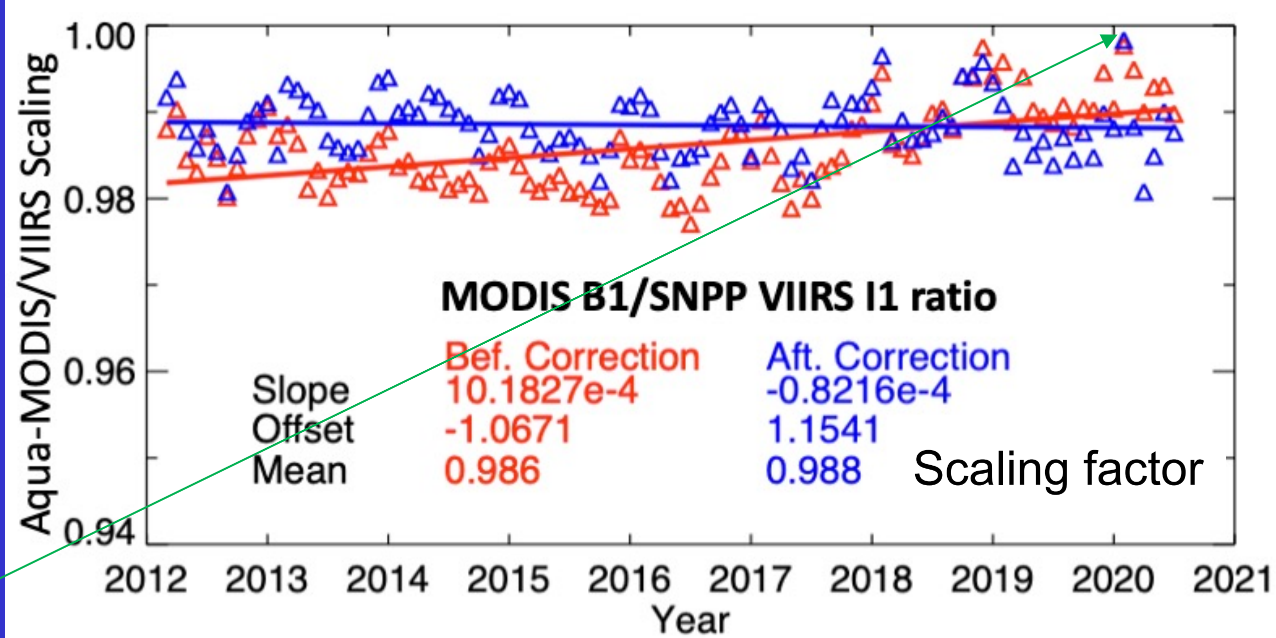


SNPP-VIIRS to Aqua-MODIS radiometric scaling

SNPP-VIIRS I1 C1/Aqua-MODIS B1 C6.1
Jan 2011

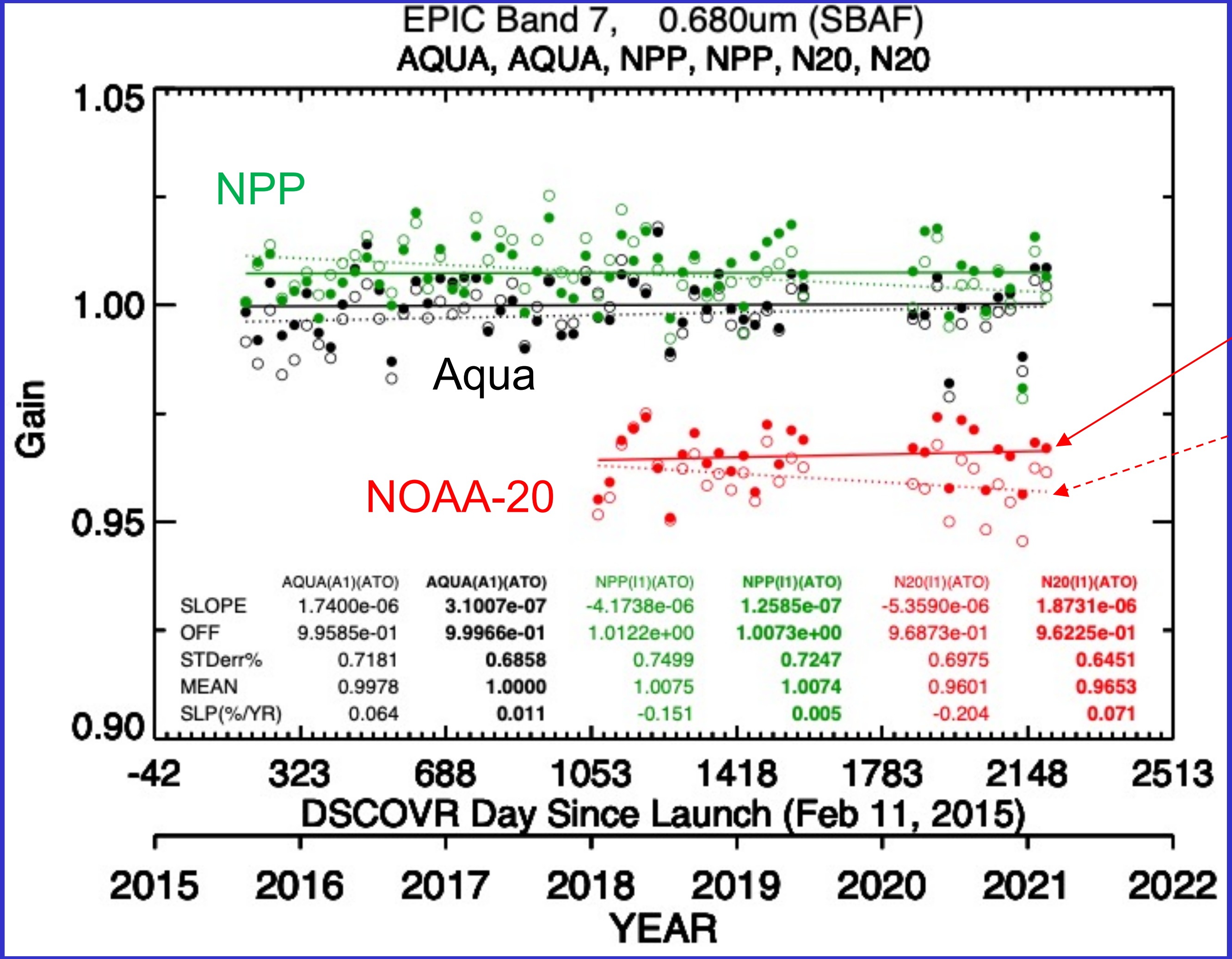


All-sky ocean 0.5 gridded coincident ray-matched reflectance comparison



- Without drift corrections, radiometric scaling between MODIS and VIIRS is time-dependent
- After drift corrections, a single scaling factor is applicable for the entire record

DSCOVR EPIC validation of imager drift corrections



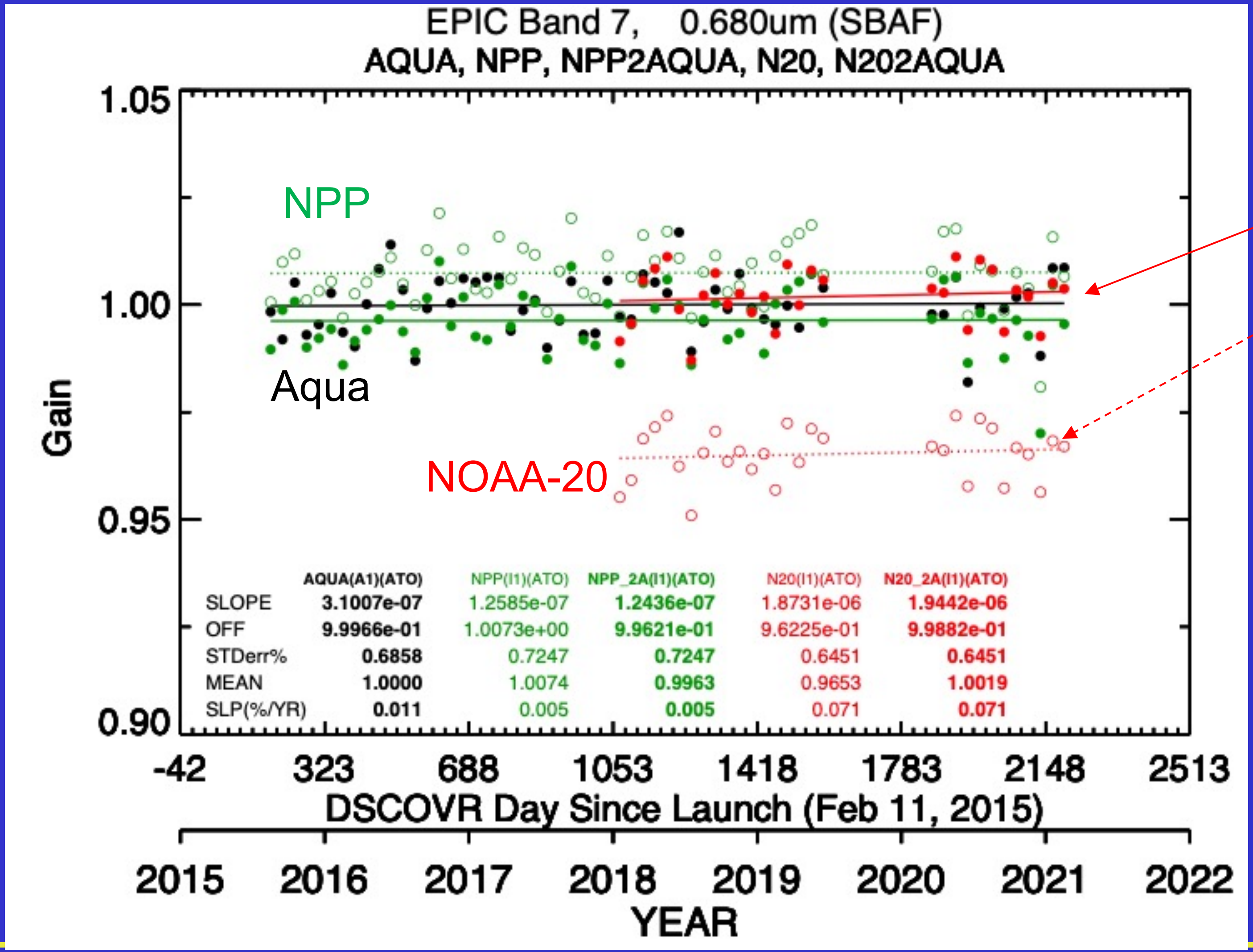
Before N20 drift correction, -0.2%/year
After N20 drift correction, +0.07%/year

Solid line with drift correction

Dotted line before drift correction

- The EPIC imager calibration is nearly stable in orbit
- Perform monthly all-sky ocean 0.5 gridded coincident ray-matched EPIC/imager reflectance comparison

EPIC validation of VIIRS radiometric scaling to Aqua



Solid line with scaling

Dotted line before scaling

Before NPP scaling disagrees by 0.7%
After NPP scaling within 0.4% with Aqua

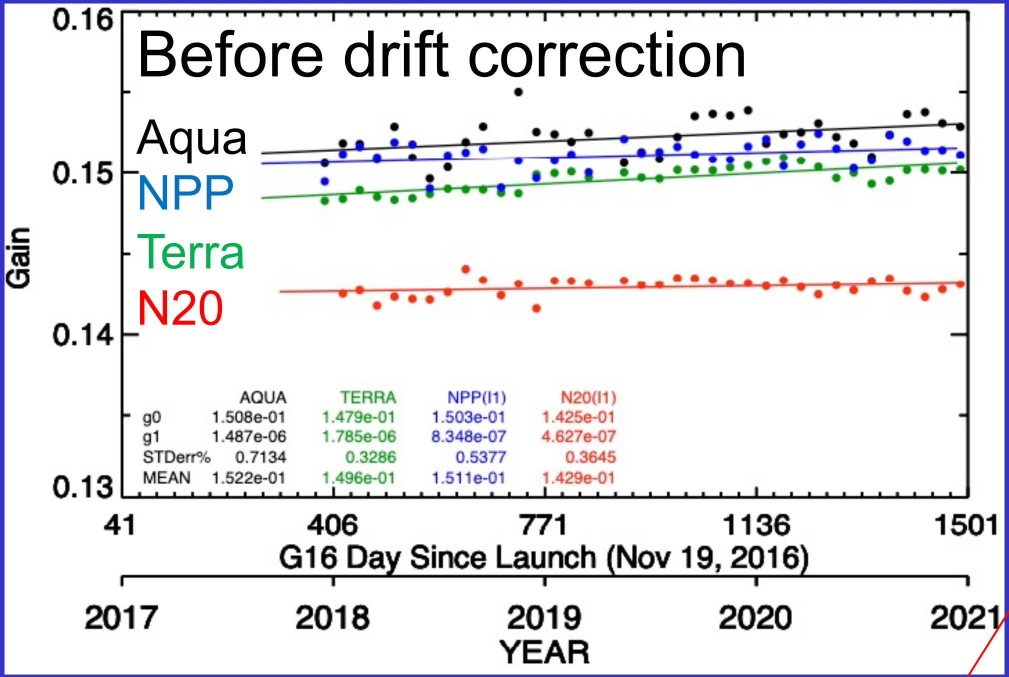
Before N20 scaling disagrees by 3.5%
After N20 scaling within 0.2% with Aqua

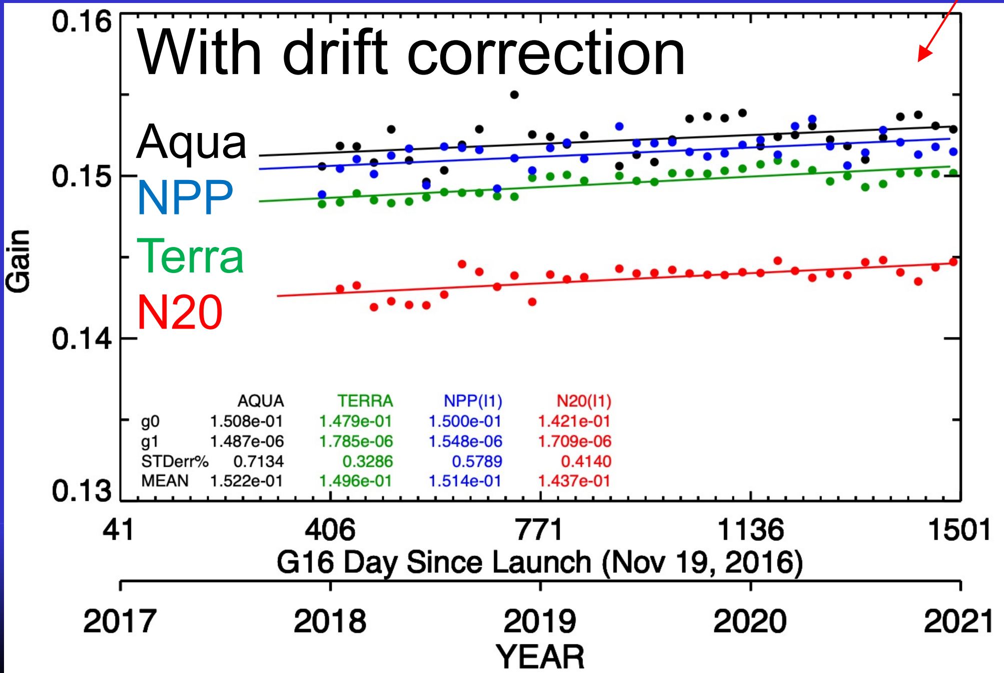
- The EPIC imager observes all local hours and is suited to calibrate drifting local time sensors

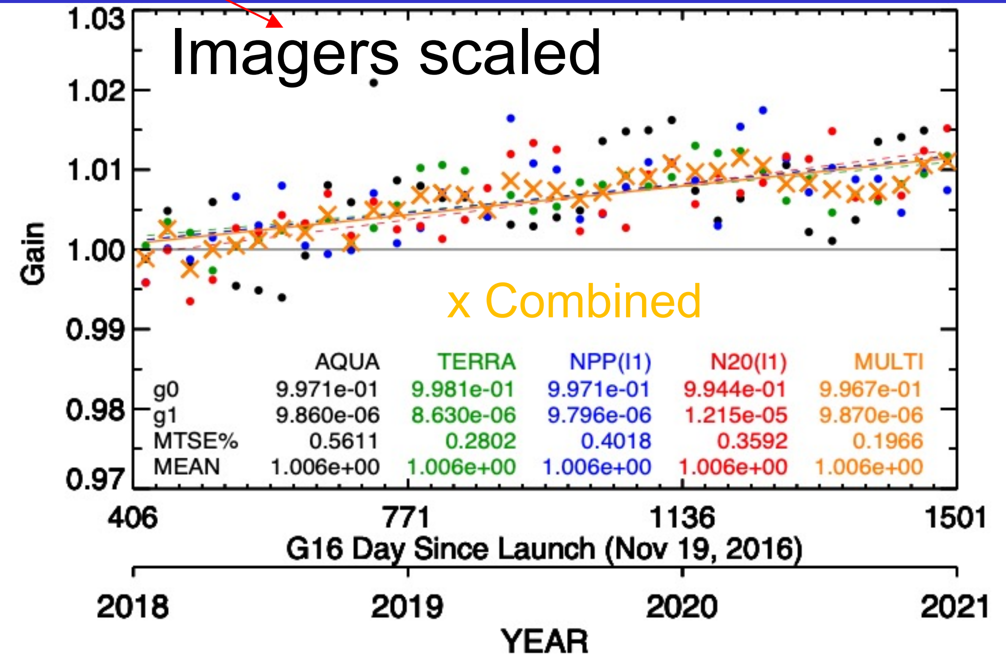
GOES-16 ABI to LEO inter-calibration

- GOES-16/imager monthly all-sky ocean 0.5 gridded coincident ray-matched reflectance comparisons

- All imagers estimated the GOES-16 0.65µm band degradation at 1.1%±0.2% over the 3-year record
- The combined imager had the lowest standard error of 0.2%

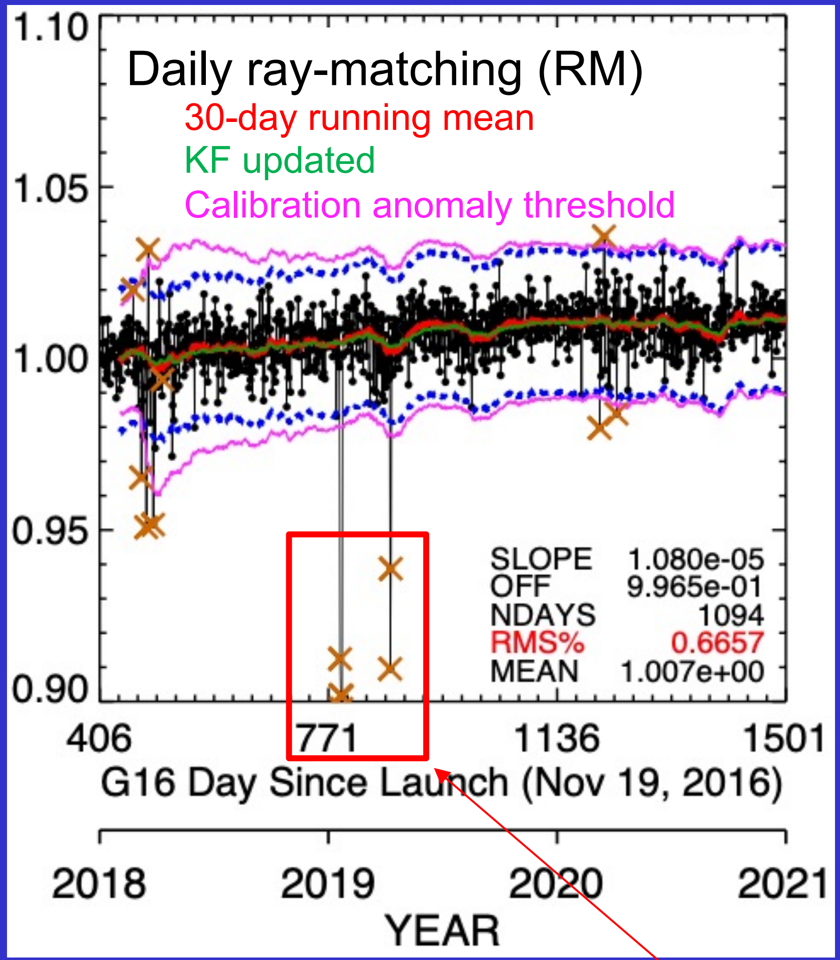


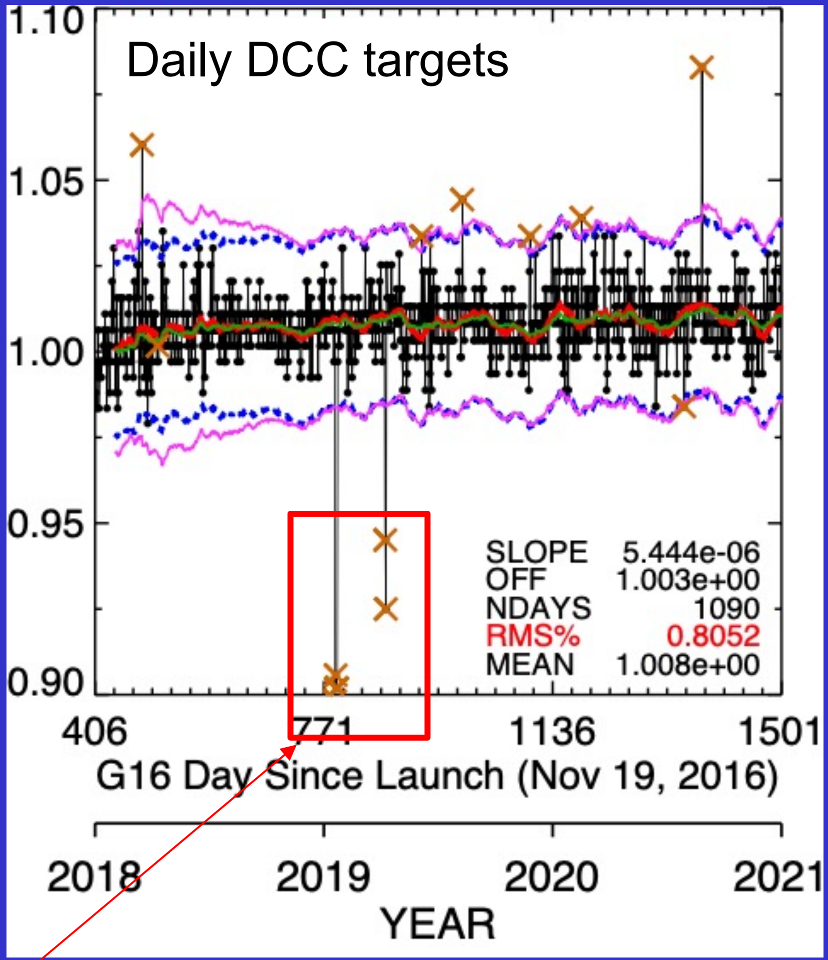


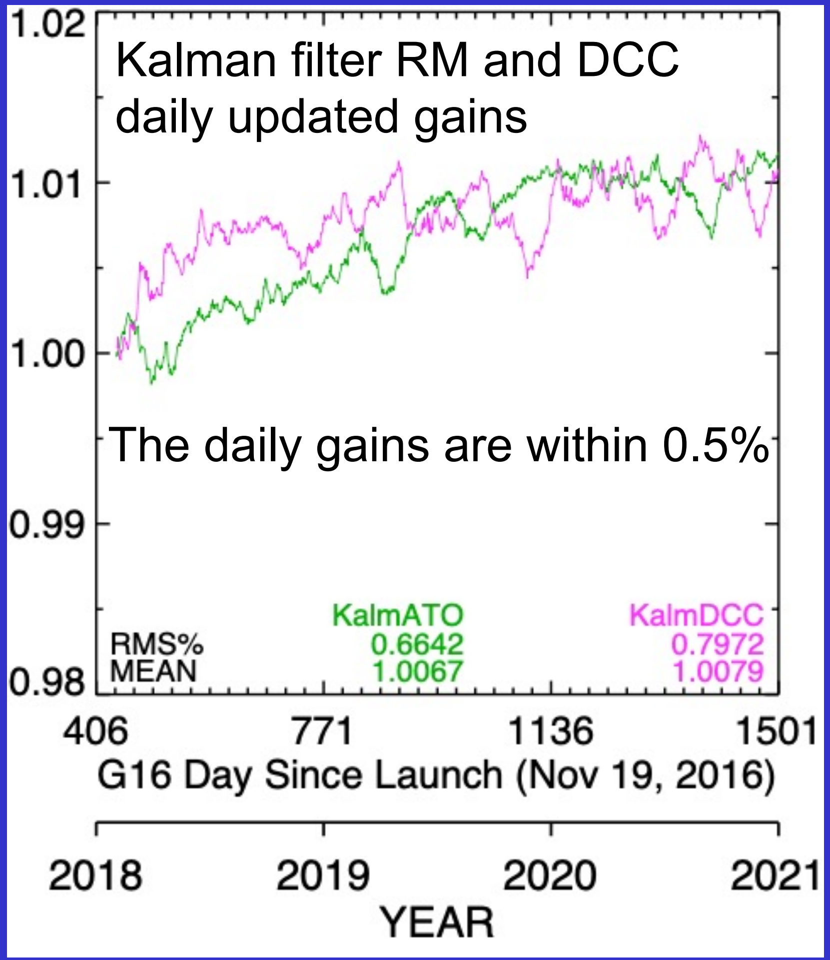


GOES-16 Daily monitoring

G16 L1B daily radiances are occasionally spurious







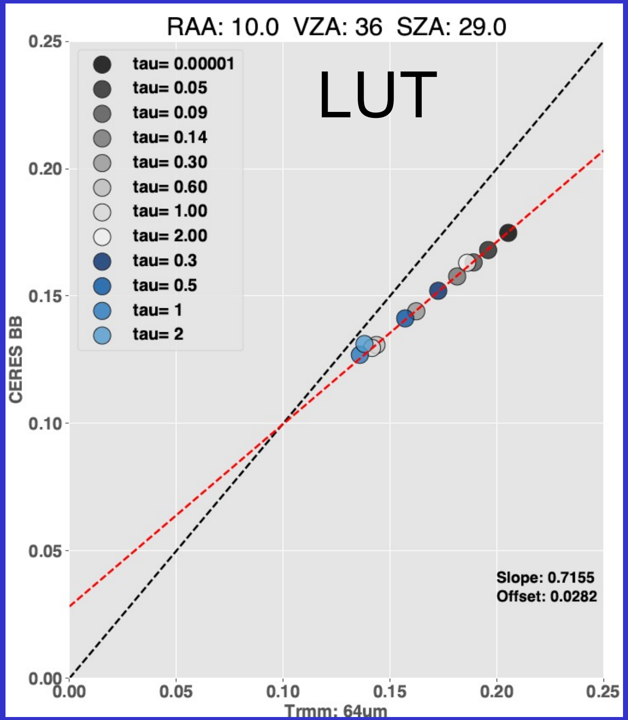
GOES-16 calibration events verified on the NOAA log web page

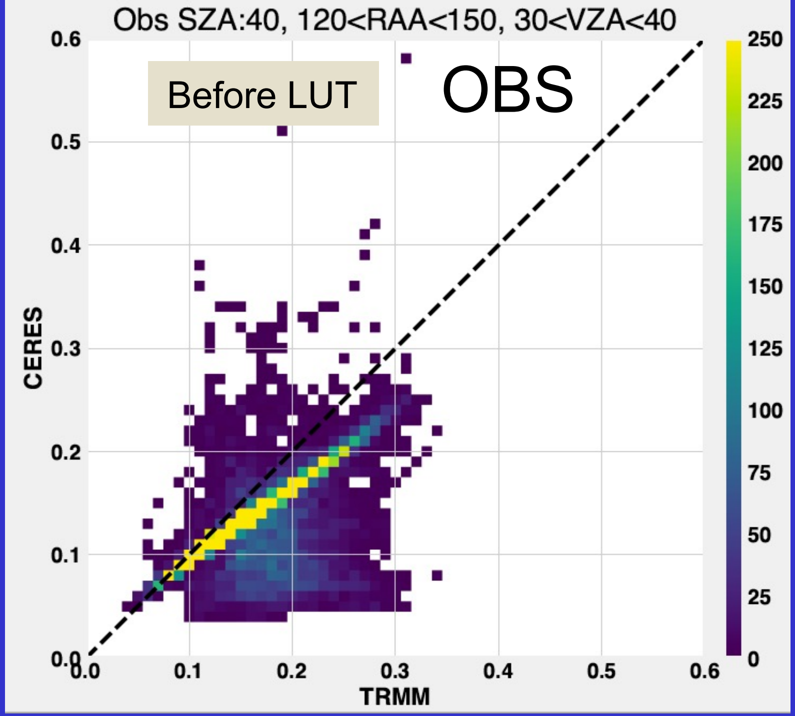
- If both RM and DCC daily gain exceed ±2.5% from the KF, the day is checked for possible calibration anomaly and removed before processing

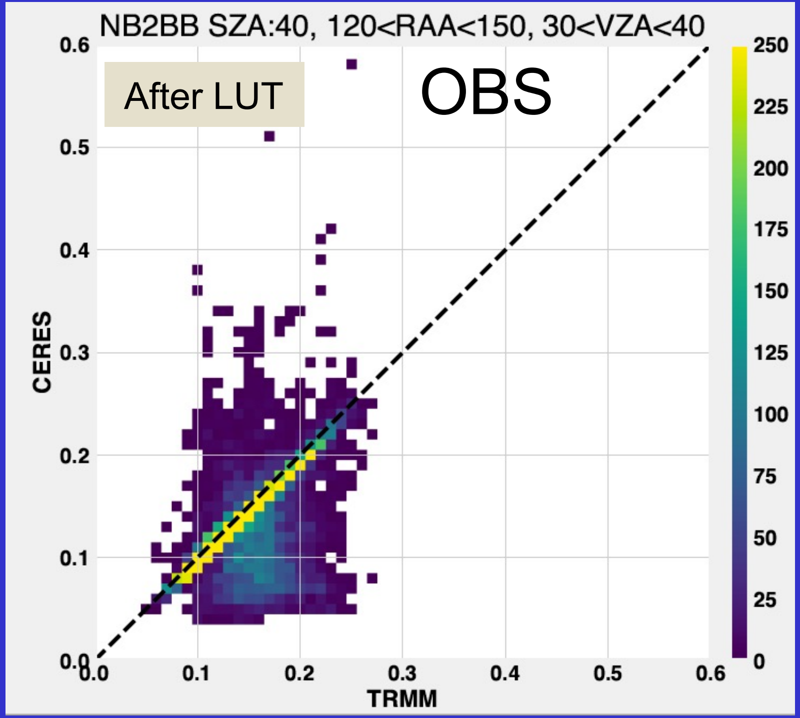
GEO SW NB to BB Ed5

- Convert GEO visible narrowband (NB) channel directly to broadband (BB) radiance using hyper-spectral RTM, ~ 2500 wavelengths (0.2µm to 5µm)
  – Eliminate the Ed4 two step process of converting GEO to MODIS-like and then using empirical MODIS-like to BB radiance (Ed4 SW NB to BB LUT codes no longer exist)
  – Each GEO will have its own customized RTM LUT by convolving the RTM hyper-spectral radiances with the GEO spectral response function
- Continue to use the TRMM ADMs to convert BB radiance to flux
  – TRMM orbit precesses and provides complete solar zenith angle sampling

Clear-sky Ocean over Glint SW NB to BB strategy

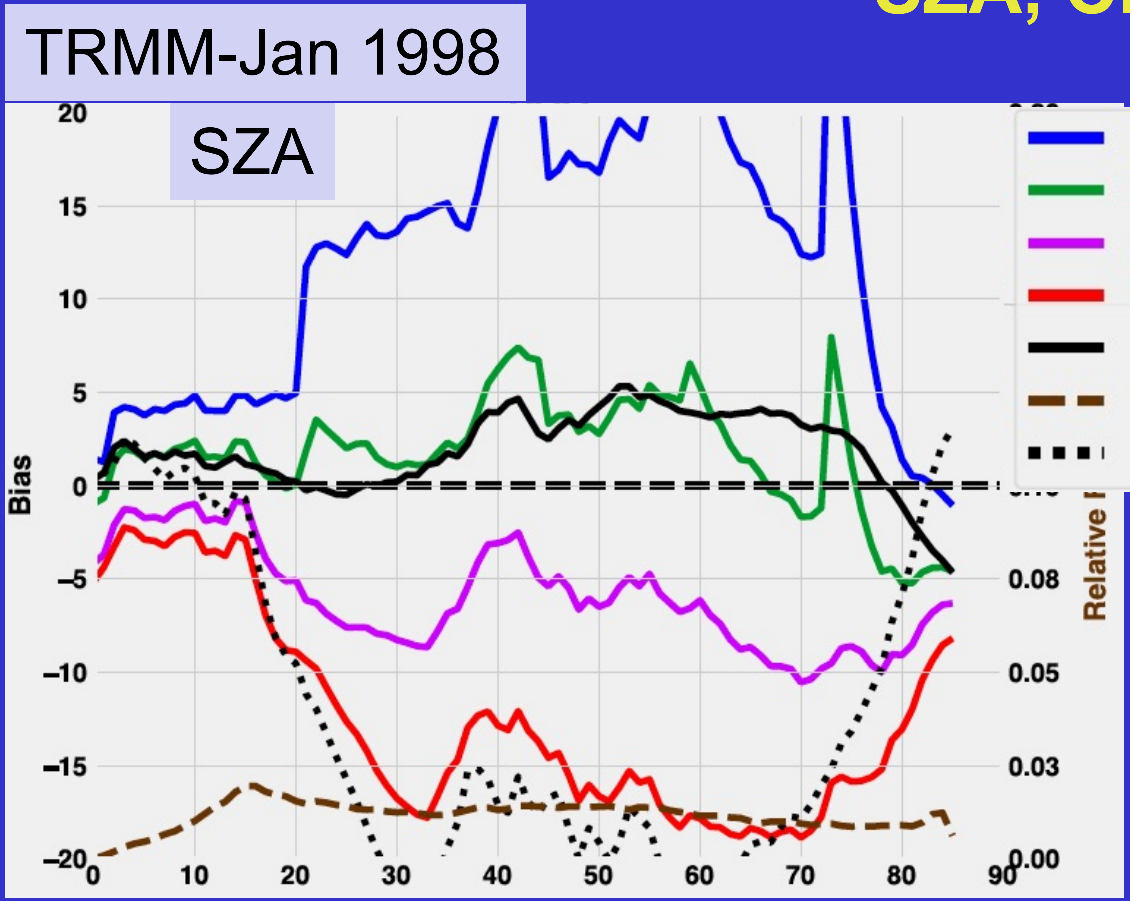


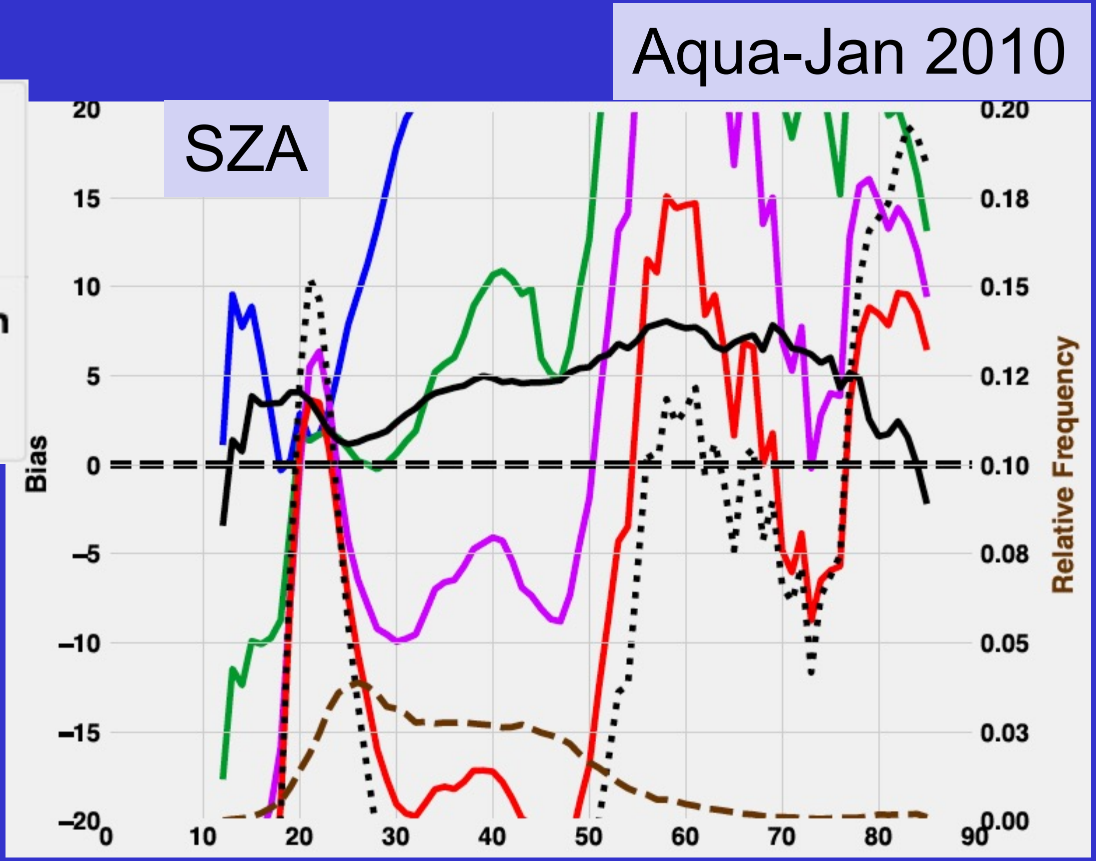




- Both the LUT and TRMM VIRS NB and CERES BB reflectances show a linear relationship for glint angular conditions
- Rather than rely on a single clear-sky optical depth LUT bin, regress the NB and BB LUT aerosol (or water cloud) optical depth bin NB and BB reflectances within an angular bin
- We use the same approach for overcast water and ice clouds to convert NB reflectance to a BB reflectance

SZA, Clear-sky Ocean



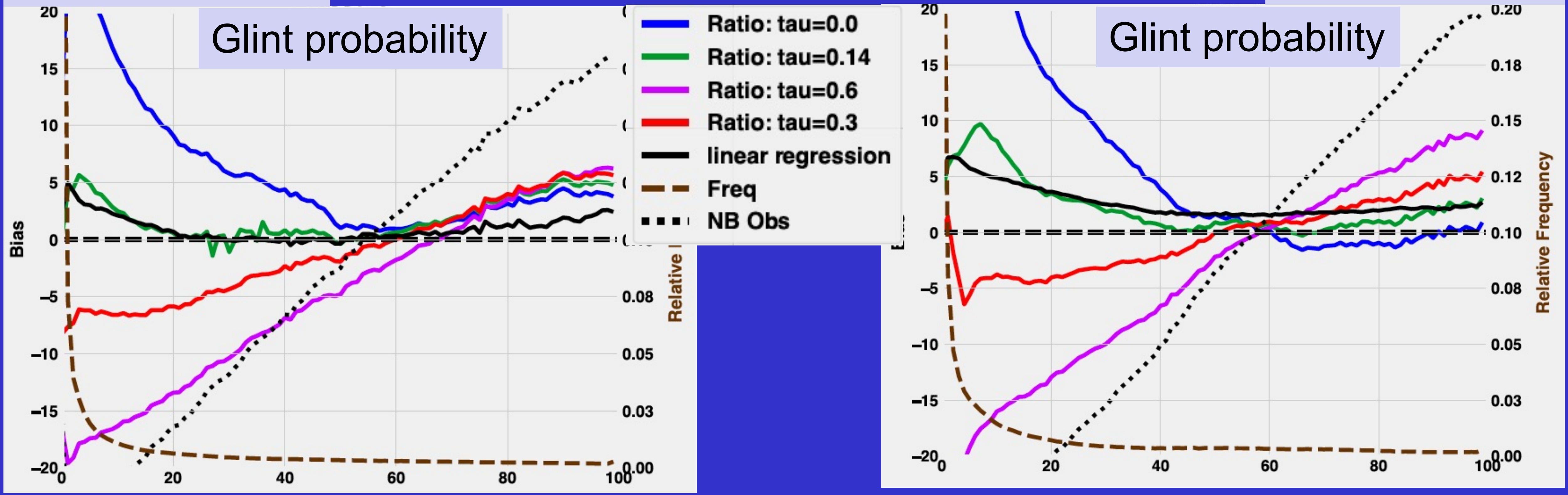


• The linear regression through clear-sky ocean aerosol optical depth NB and BB reflectance bins has the least dependence by SZA

Glint probability, Clear-sky Ocean

TRMM-Jan 1998

Aqua-Jan 2010

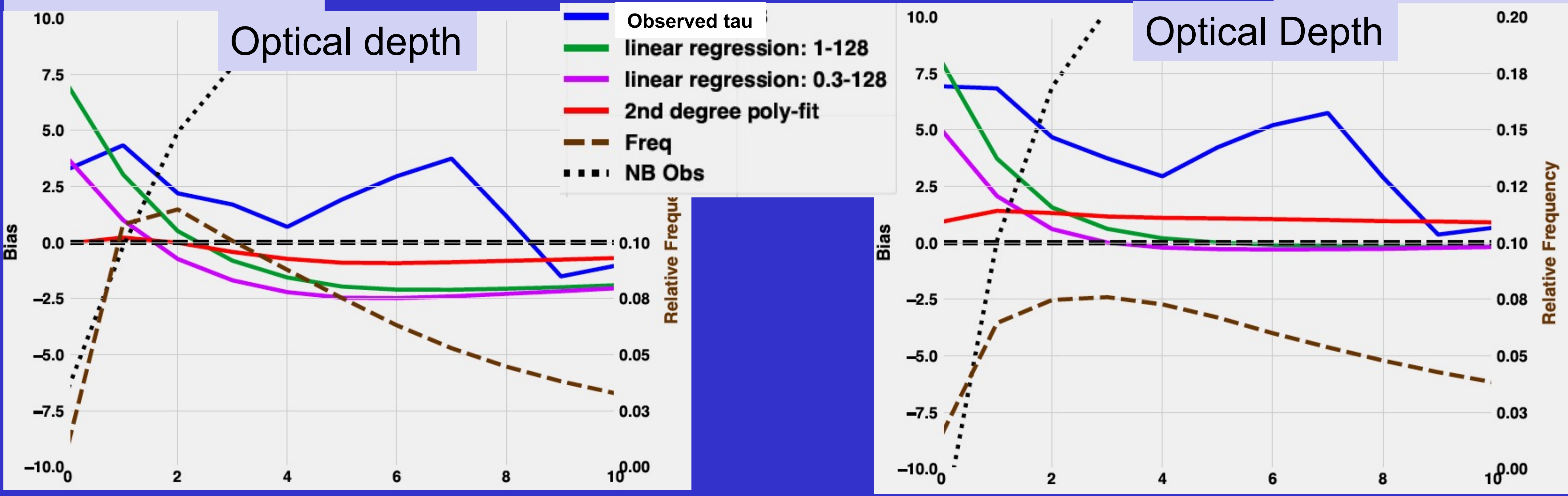


• The linear regression through clear-sky ocean aerosol optical depth NB and BB reflectance bins has the least dependence by glint

Optical Depth, Cloudy Ocean

TRMM-Jan 1998

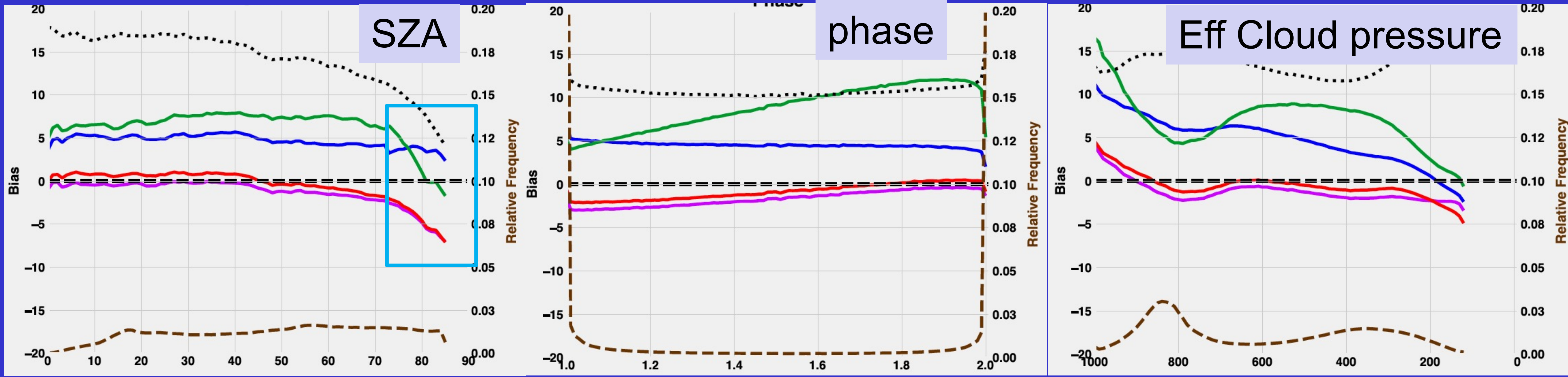
Aqua-Jan 2010

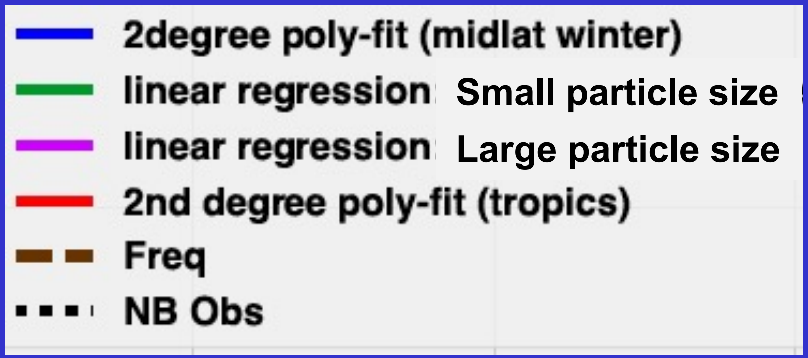


- The observed cloud optical depth NB and BB reflectance bin has the greatest dependency with COD
- The linear regression through the COD LUT bin NB and BB reflectances is flat, except at low optical depths
- Adding 0.3 and 0.5 COD LUT bins is an improvement for low COD
- Apply 2nd order regression through COD LUT NB and BB ref has least dependency with COD

SZA, Cloudy Ocean

TRMM-Jan 1998





- The linear or 2nd order regression is flat with phase and eff pressure but not SZA
- **midlatitude** profile linear regression is flat with SZA and phase but not eff pressure
- The **smaller particle size** linear regression has dependencies with SZA, phase and eff pressure

- Continue to use large particle size in SW NB to BB

SW NB to BB Validation Strategy

- Convolve LUT hyper-spectral radiance with GEO SRF as a function of scene-type
- Optimize LUT approach with Aqua MODIS/CERES and TRMM VIRS/CERES data
  - Ocean is finished
  - land and desert LUT, apply same methodology as Ocean
  - Compare with Ed2 SW NB to BB
- Validation DATASETS
  - Terra, Aqua, TRMM SSF (footprint)
  - Terra, Aqua, TRMM SSF SSF1deg (gridded),
  - GERB
  - Coincident GEO with CERES datasets

Work Since Last Science Team Meeting

- The EBAF & lites, SYN1deg, CldTypeHist, and FluxByCloudType products have all been processed utilizing N20 fluxes to fill in the Aqua data gap during the last two weeks of August 2020
  - Needed to switch from CERES window and LW channels as well as from MODIS to VIIRS channels
  - Validated by comparing the monthly fluxes between with and without adding N20 in the products
- The Clouds and TISA groups has implemented a nighttime IR-only (9:30 training hour) and daytime VIS/IR (17:30 training hour) KD tree algorithm to replace GOES-17 has nighttime degraded imagery
  - Use WV and cloud phase to define KD tree hours, use daytime training hour to improve land heating IR BT
- GOES-13 is now actively scanning over the Indian Ocean (60 E)
  - Verified its radiometric performance with MODIS and VIIRS. Can be used as a backup for the region
- Combine EBAF and FLASHFlux monthly fluxes as part of EBAF processing to produce an internal real-time flux product
  - Worked with the FLASHFlux group to compute monthly TOA/SFC fluxes and clouds from the FLASHFlux daily mean products